

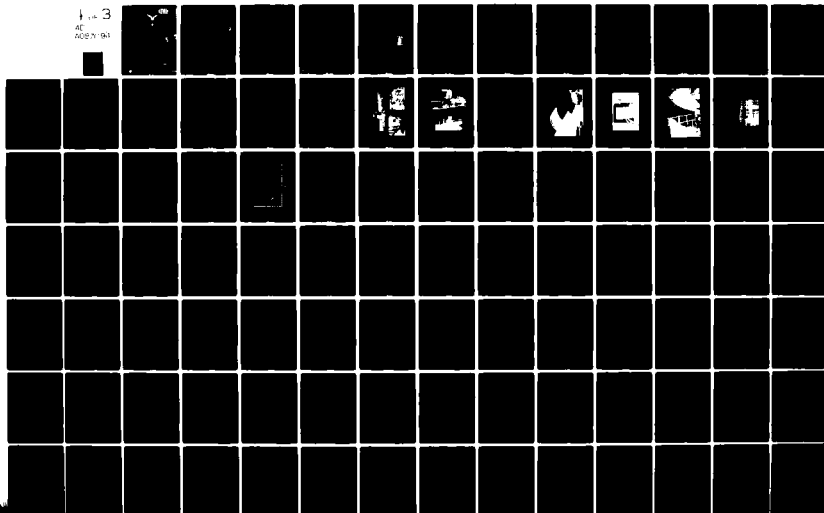
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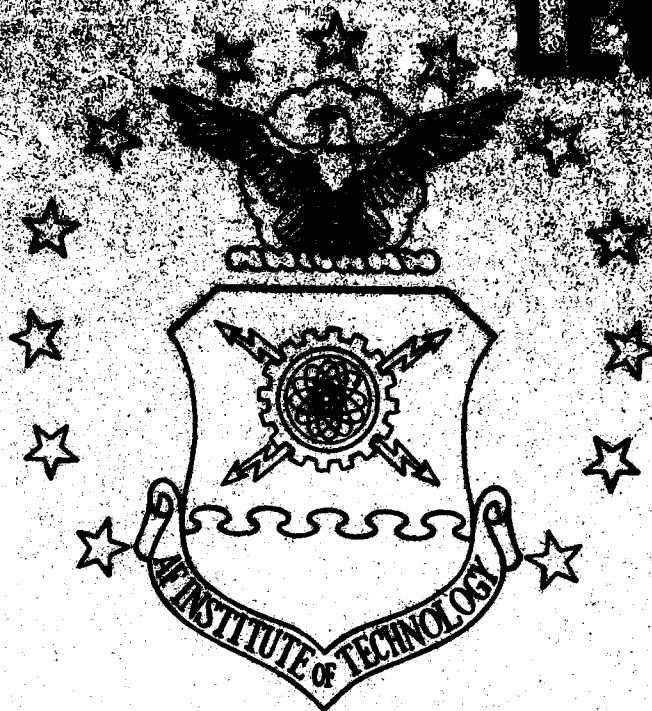
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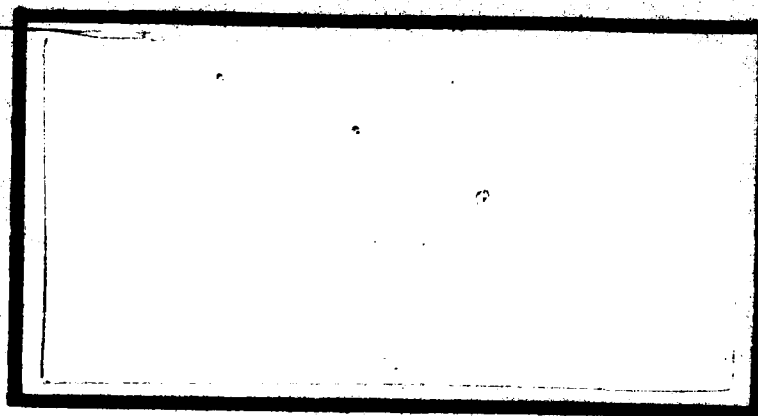
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**AN ANALYSIS OF THE FUTURE REQUIREMENTS  
FOR MATERIALS HANDLING EQUIPMENT IN  
THE MILITARY AIRLIFT COMMAND**

**Christopher Carson, Second Lieutenant, USAF  
Charles D. Munson, Second Lieutenant, USAF**

**LSSR 35-80**

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Civilian wide-bodied aircraft are presently used to augment the Military Airlift Command's airlift capability. Many analysts believe that this wide-body usage will increase in the future. However, even today, the basic 463L materials handling equipment system (e.g., K-loaders) cannot accommodate civilian wide-bodies. Cargo loader adapters and modifications have proven infeasible, necessitating the use of elevators for loading/unloading operations. Therefore, the purpose of this study was to examine whether the United States Air Force should continue to write specifications around the present K-loaders, or initiate acquisition of a cargo loader capable of interfacing with both military aircraft and civilian wide-bodied aircraft. The examination of these two decision alternatives involved three main phases: (1) a forecast of the future U.S. wide-body and narrow-body market, (2) a determination of Military Airlift Command's future loader requirements based on predicted changes in cargo activity, and (3) a net present value analysis of system costs built on various policies for loader replacement. After the results of these phases were obtained, the authors concluded that the Air Force should continue to acquire, operate, and maintain its present K-loader system.

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AN ANALYSIS OF THE FUTURE REQUIREMENTS  
FOR MATERIALS HANDLING EQUIPMENT IN  
THE MILITARY AIRLIFT COMMAND

A Thesis

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology  
Air University

In Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Facilities Management

By

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June 1980

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has been accepted by the undersigned on behalf of the  
faculty of the School of Systems and Logistics in partial  
fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN FACILITIES MANAGEMENT

DATE: 9 June 1980

Thomas C. Haxington  
COMMITTEE CHAIRMAN

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## CHAPTER I

### INTRODUCTION

#### Background

The military currently utilizes civilian wide-bodied aircraft (WBA) to supplement their airlift capability. Because of the unique cargo-carrying characteristics of WBA, this utilization may increase. If this occurs, it is of primary importance for the United States Air Force (USAF) to have the necessary materials handling equipment (MHE) on hand to load/unload these aircraft.

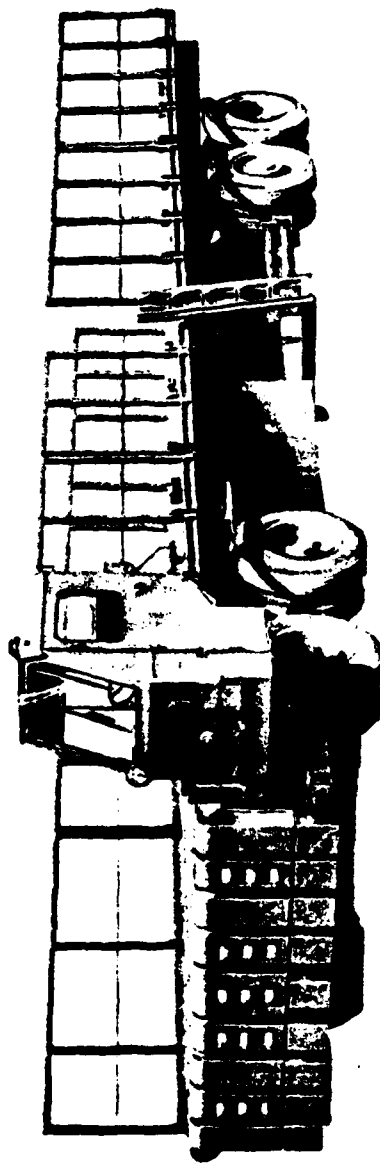
Several studies predict that the number of WBA in commercial use will continue to rise during the next decade. Presently, the DC-10 and the B-747 aircraft represent the total population of cargo-capable WBA in the free world. Simultaneously with this projected increase in numbers of WBA, it is predicted that the population of narrow-bodied aircraft (NBA) in commercial use will decrease (14; 33; 34; 39; 40). These two trends, the growing population of WBA and the decreasing population of NBA, are changing USAF MHE requirements with respect to supporting Category B missions and, upon activation, the Civil Reserve Air Fleet (CRAF). Category B missions involve contracting by the Military Airlift Command (MAC)

of commercial aircraft within the CRAF to deliver cargo between USAF bases. The CRAF consists of those civilian aircraft included in military contingency plans for the purpose of supplementing MAC's airlift capabilities in the advent of war. In either case, the USAF's basic 463L cargo handling system cannot load/unload the main deck (upper lobes) of civilian WBA (43:1).

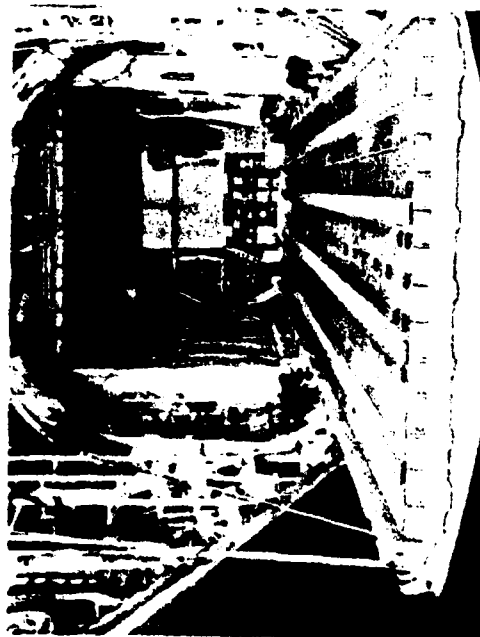
The 463L system facilitates the loading/unloading of all USAF cargo aircraft by using a standard type of transporter loader and incorporating the use of a singular pallet type to serve as a base cargo-carrying unit. The 463L system consists of the complete interfacing of the USAF's 40K (40,000 lb. cargo load capacity) and 25K transporter loaders with the USAF C-5, C-141, C-135, and C-130 aircraft. The 40K and 25K loaders may also service all U.S. civilian cargo aircraft except WBA (33:5). With respect to rail lock-in mechanisms, winch systems, and rollerized beds (see Figure 1), the standard 463L pallet is fully compatible with K-loaders and military cargo aircraft.

The main incompatibility between the 463L system and the civilian WBA is the inability of the 40K and 25K loaders to elevate cargo to the height of the WBA's upper lobes. K-loaders extend to a height of 13'0" while the height of WBA upper lobes ranges from 15'6" to 18'1" (see Figure 2) (33:10). Other significant problems are related

40K Transporter Loader



Aircraft Rail System



A Completely Build-up 463L 88"x108" Pallet,  
With Nets, Ready to be Loaded



Fig. 1. 463L System (33:22)

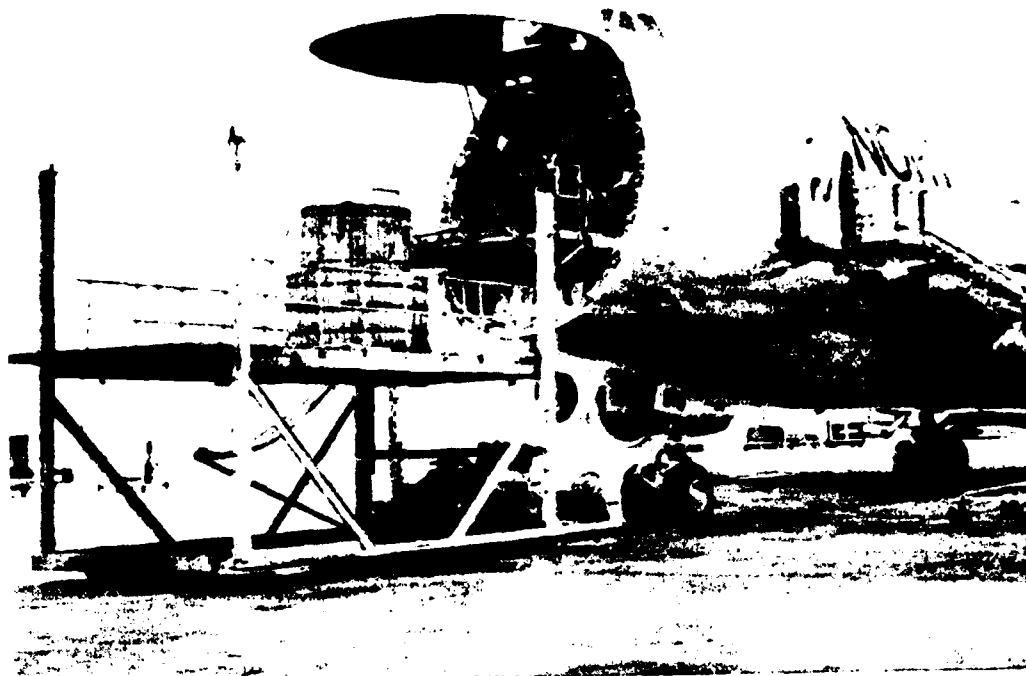


Fig. 2. Upper Cargo Lobes of WBA (33:38,72)

to the mating between K-loaders and WBA lower cargo holds (lower lobes) and the actual loading of 463L pallets into civilian WBA. USAF K-loaders may load/unload WBA lower lobes; however, a loader-bridging modification must be made to allow an interface between loader and lower lobe (see Figures 3 and 4). Other factors such as safety and excessive requirements for manpower and equipment place into doubt the feasibility of using K-loaders to service WBA lower lobes (34:34-35).

To deal with the incompatibility between WBA cargo holds and K-loader capabilities, the USAF has acquired commercial elevators and developed an adapter for the 40K transporter loader that increases its height of elevation to 18 feet. The Cochran 316A elevator accommodates the loading/unloading of WBA upper lobes but is unable to service the lower lobes since the elevator's "corner posts come into contact with the aircraft fuselage and result in a 5 foot gap between the elevator's platform and the lower lobe [34:39]" (see Figure 5). The 40K loader with Adapter (see Figure 6) is also able to service WBA upper lobes. However, this modified unit now serves no other purpose since it is unable to service WBA lower lobes or any military cargo aircraft. In addition, a common problem to both the Cochran 316A elevator and adapted 40K loader is that they must be partially disassembled to be transported in a C-141 aircraft, unlike the standard 40K and 25K loaders (21:22).



Fig. 3. Center-Lower Cargo Lobe of a WBA (34:14)



Fig. 4. 40K Loader with Bridging Device (34:36)

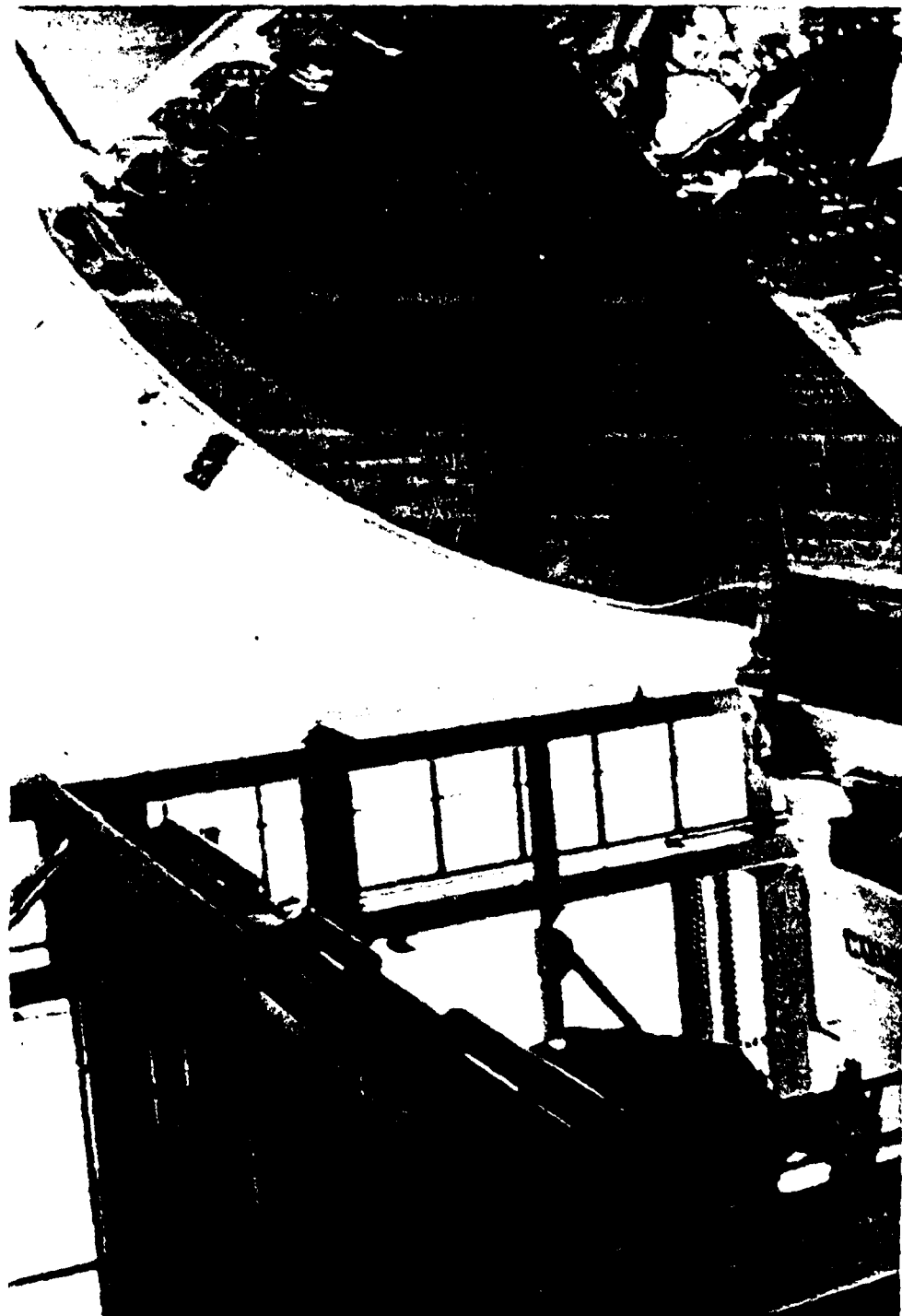


Fig. 5. Cochran 316A Elevator at Lower Lobe (34:38)



Fig. 6. 40K Transporter Loader with Adapter (33:78)

### Problem Statement

In essence, the USAF maintains a dual system of cargo loaders. Standard 463L K-loaders accommodate all military cargo aircraft, NBA, and the lower lobes of civilian WBA. The Cochran 316A elevator and adapted K-loader may service only the upper lobes of civilian WBA. The problem that this research addresses is whether the USAF should continue to acquire, operate, and maintain the dual system of cargo loaders, or begin a conversion to a cargo loader capable of interfacing with both military cargo aircraft and civilian WBA.

### Literature Review

#### An Existing Need for Research

One may begin to wonder whether a need to study the conflict between the 463L cargo handling system and WBA really exists. In fact, the need does exist. First, the current 463L system problems in the loading/unloading operations of WBA do not represent a unique situation which has not occurred in the past. Second, those who are involved in the research and development of MHE should not even be the least bit surprised that the question concerning the continuation of writing specifications around the 463L equipment system has arisen. A past problem which seems to foreshadow the present military MHE issue can be traced back to the years following World War II as

indicated in a thesis entitled "Cargo Handling Equipment for Future Long-Range Aircraft."

The author, USAF Captain James D. Patterson, stated that during these post-war years it became evident to the military forces that the stockpiling of sufficient material supplies at many of the United States (U.S.) defense installations was both unpractical and exorbitantly expensive. The experience gained in previous airlift operations was assessed by the USAF to ascertain the type of aircraft and MHE required to support military forecasts of logistic requirements. The USAF had several studies carried out by industry to determine logistic airlift demands. One of these studies specified the C-124 aircraft, which initially entered service in 1950, as a Strategic Air Command (SAC) support aircraft and a Tactical Air Command (TAC) troop carrier. Later, the C-124 was accommodated to Military Air Transport Service (MATS) missions of long-range logistics support. With the capability of this aircraft, the USAF had a piece of equipment that could provide global logistical support. However, even with the development of the C-124 aircraft, only a small amount of cargo handling equipment was designed to promote efficient loading and unloading of cargo. Loading of cargo on the C-124 was typically done one piece at a time resulting in a waste of manpower and time (30:2). In his thesis Patterson pointed out that

historically, the cargo aircraft is initially developed and frequently years later a device or system to service this same aircraft is developed. Patterson wrote that

With the present increased demands for air transportation of men and material and the recent trends in larger cargo aircraft, it can be concluded that even larger and longer-range aircraft will be produced in the future. Furthermore, if the present trend toward increased air cargo requirements are continued, there is a definite cause for concern [30:30].

Present cargo handling equipment cannot support future large long-range aircraft in a manner that would provide minimum turn-around time [30:ii].

He recommended that

Future studies for cargo handling equipment be initiated simultaneously with aircraft development. The extent and design of the cargo handling equipment required for a new generation of cargo aircraft will depend largely on aircraft design and capacity. [30:ii].

Patterson's conclusions and recommendations, made in 1966, predicted that a problem like today's "wide-body" situation would occur. His prediction was based only on analysis of past military MHE development. In reality, Patterson's study also supports a future worsening of the situation or simply a projected increase in the number of WBA without a change in the current 463L system.

### A Growing Interest in Military MHE

In the past few years, people have been starting to take Patterson's 1966 ideas seriously. Key examples of the growing concern about future military MHE are two analyses completed by the USAF Assistant Chief of Staff, Studies and Analyses. One study is entitled Analysis of Materials Handling Equipment for Wide-Bodied Aircraft (Saber Readiness-India) and pertains to MHE loading and unloading the upper lobes of WBA. The other study is entitled Analysis of Materials-Handling Equipment for Lower Lobes of Wide-Bodied Aircraft (Saber Readiness-Kilo) and pertains to MHE loading and unloading the lower lobes of WBA.

Both studies indicated that there has been considerable interest shown recently by the Department of Defense (DOD), the airline industry, and the Congress with respect to the use of WBA for augmenting military airlift in the future (33:iii; 34:iii). As a simple illustration of the relative importance of these reports to the DOD, personnel at MAC Headquarters imply that they use the Saber Readiness-India like "the Holy Bible [36]."

In the past the USAF has provided the cargo loaders and loading teams when civilian cargo-capable aircraft operate through military aerial ports (33:2). Thus, an increase in interest shown in the use of WBA has created a similar increase in interest in the subject of

MHE for these wide-bodies. Yet, why has the WBA "come into the limelight"? As shown by Saber Readiness-India and Saber Readiness-Kilo, two major reasons account for the ever-growing interest in this large aircraft.

The first main reason for today's interest in the WBA is the estimated change in the mix between narrow-bodies and wide-bodies in U.S. flag carriers' long-range international cargo aircraft (see Figure 7).

The Boeing Company and the Military Airlift Command estimated the phase-out of B-707/DC-8 cargo-capable aircraft from 1977 to 1990 and a corresponding increase in wide-bodied (B-747/DC-10) cargo-capable aircraft. The estimated increase in wide-bodies was computed with and without possible modification of wide-bodied passenger aircraft to enhance their cargo-carrying capability [33:15].

This future increase in wide-bodies as predicted by the USAF Assistant Chief of Staff, Studies and Analyses, is supported by several others who have made similar analyses on future aircraft trends. For example, one study which was completed through the U.S. Department of Transportation and entitled "Forecasting Models for Air Freight Demand and Projection of Cargo Activity at U.S. Air Hubs" documented a method for projection of air cargo activity at all U.S. air hub airports. The report's basic conclusion via a computer program was that cargo demand and activity at all U.S. air hubs will increase in the future. Thus, this study suggested the same predictions as Saber Readiness-India and Saber Readiness-Kilo in that

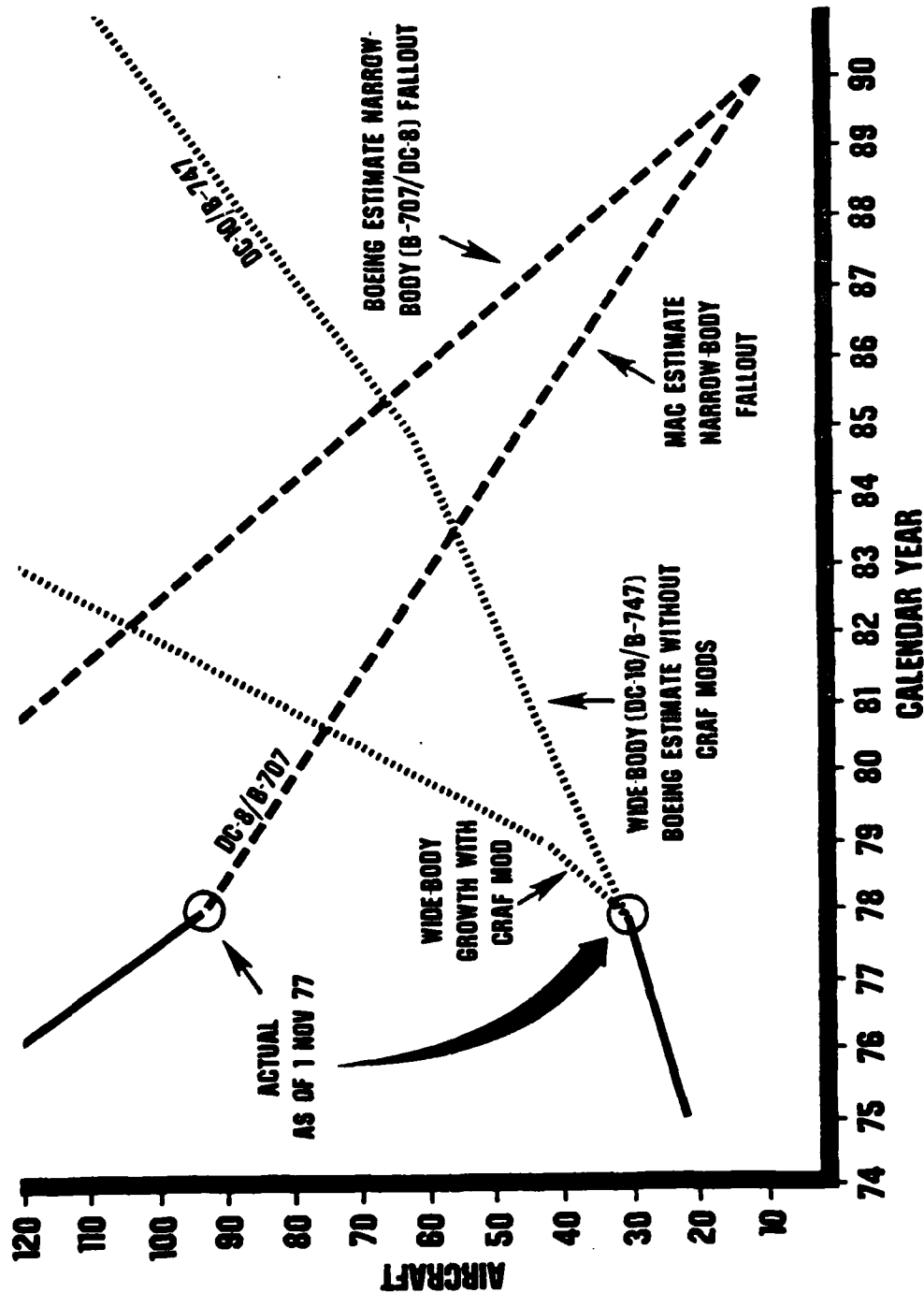


Fig. 7. Mix of NBA and WBA (33:14)

wide-bodies will increase to satisfy the projected increase in cargo activity (27). In addition, the Boeing Company presently is under contract to build the new B-757 and B-767 with the B-777 in the design phase, again supporting estimated future increases in wide-bodies. Finally, MAC is in the process of purchasing twenty-three Cochran 316A elevators (or another brand of loader with the same Cochran 316A design) which will supplement the existing 463L system. These Cochran elevators, of which MAC already has twelve, provide the capability to reach the high main decks of WBA. After this purchase MAC will become one of the leading possessors of this commercial-type elevator. For instance, MAC would own more elevators than most airline companies (36). They would also own more of these loaders than all of the other major USAF commands together or the Navy (17; 36). Thus, the buying of these loaders not only supports the projected increases in wide-bodies, but also justifies a concentration of research on MAC and its 463L system inventory.

During a time of growing concern about fuel shortages, the reader may tend to question why the number of WBA is predicted to increase rather than decrease in the future. There are two key points which are the basis for this projection. First, the new wide-bodies such as the B-757 and B-767 are actually more fuel-efficient than present

aircraft (39). Also, in general, the WBA have substantially lower operating costs than the NBA (27:1). Second, Saber Readiness-India indicates that a new aviation noise policy and regulation which became effective 1 January 1977 will have a definite effect on the mix between narrow-bodies and wide-bodies. This policy requires that all airline aircraft not meeting Federal Air Regulation 36 noise levels will be retired from the fleet or retrofitted to meet those levels according to a phased timetable.

There is little likelihood that the B-707/DC-8s will be retrofitted. These aircraft pose serious problems because of their age and their adverse environmental impact [33:15].

While many estimates may differ as to the phase-out rate of the older, less-efficient, and noisier NBA with an accompanying increase in wide-bodies, it appears inevitable that the number of WBA will increase quite significantly in the future. This occurrence will have far-reaching impact upon the overall cargo loader requirement for WBA (33:15).

The second major reason for the ever-growing interest in WBA is the higher cargo-carrying capability which they possess over the narrow-bodies. According to static loading tests and recent usage, the wide-bodies' upper-and-lower-lobe potential has clearly been demonstrated. For example, the lower-lobe capability alone of

211 wide-bodied CRAF aircraft including passenger baggage is equivalent to thirty-nine C-5s or 127 C-141s (34:13). Assuming a future increase in the number of WBA, this upper-and-lower lobe capability would prove to be a tremendous advantage to the CRAF in the event of an emergency activation. In addition, this wide-body capability could be greatly increased with the advent of two technological advances: CRAF modifications and U.S. acquisition of Advanced Tanker/Cargo Aircraft (ATCA).

First, in relation to CRAF modifications, the DOD proposed to Congress that civilian WBA passenger aircraft be modified to increase their usefulness for carrying cargo (33:2). The initial appropriation of \$7.5 million was approved by Congress in 1977 for this intention; however, the project has not really advanced past this step (33:2; 39). Modification of these passenger aircraft would involve modifying the fuselage to include a cargo door, strengthening the aircraft's floor beams, and installing an internal cargo handling system such as rails or rollers. This modification would give a wide-body passenger aircraft the cargo capability of the freighters and convertibles which presently exist in the CRAF (39). Today, the CRAF inventory consists of forty-six cargo and 165 passenger WBA (see Figure 8). With respect to the forty-six cargo wide-bodies, the letter "F" indicates a pure freighter specifically designed and built to carry

SEGMENT	CARGO	PAX	STAGE		
			I	II	III
DOMESTIC					
3 DC-9-30CF, 25 L-188C, 12 L-100-30	40			38	40
ALASKAN					
5 B-737-200C, 2 C-46, 1 L-188C					8
SHORT RANGE INTL					41
B-727 QC	41				
LONG RANGE INTL-PAX			8	18	250
B-707		76			
DC-8		9			
103 B-747, 6 L-1011, 56 DC-10		➔ 165			
LONG RANGE INTL- CARGO			50	69	123
B-707	9				
DC-8	68				
14 B-747-100F, 12 B-747F, 3 B-747C	29 ➔				
8 DC-10-10, 9 DC-10-30	17 ➔				

➔ DENOTES WIDE-BODIES (46 CGO, 165 PAX) CRAF TOTAL 58 125 462

Fig. 8. Civil Reserve Air Fleet Inventory (34:12)

freight. The "C" stands for a convertible aircraft or one that can be configured to carry passengers and/or cargo. The passenger-peculiar equipment is removed when the aircraft is utilized for carrying cargo (34:13). The DOD has expressed interest in modifying approximately two-thirds of the 165 passenger aircraft (40). Second, wide-body cargo capability could also be greatly increased by U.S. acquisition of the ATCA. The USAF has completed source selection plans for acquiring this new aircraft (33:2).

An ATCA may be described as an aircraft that has the range, offload, and payload to be used either as a refueler and/or cargo transporter and has the endurance to operate over longer distances than present tankers [33:2].

Thus, in summary, the advantageous cargo capability of WBA is definitely a valid reason for recent interest shown in these large aircraft.

The reader can indeed understand that estimated increases in the WBA in the future and its cargo capability make this aircraft a very important piece of machinery. In fact, one can again ponder what Patterson wrote concerning aircraft and MHE and then start to question the present 463L system. Saber Readiness-India and Saber Readiness-Kilo address the problems associated with the compatibility of the interfacing of the 463L system with WBA. These two studies also address the problems associated with the compatibility and the

interfacing of commercial off-the-shelf MHE with military aircraft. Yet, the studies do not really recommend a solution to MAC's overall problem of having to maintain a dual system of cargo loaders for the handling of both military aircraft and WBA. The two reports only identify the desirable characteristics of loaders and evaluate and compare the productivities of different loaders in handling unit equipment, built-up pallets, and stuffed containers (33:iii; 34:iii).

Some Temporary Solutions  
to the Problem

As indicated in Saber Readiness-India and Saber Readiness-Kilo, attempts have been made by the DOD to overcome MAC's current problem of having to buy commercial MHE for the loading/unloading operations of wide-bodies. One key example is the Adapter that has been recently designed and developed to provide the 40K transporter loader with the additional height capability needed to service the upper lobes of WBA. An initial operational test and evaluation (IOT&E) of the Adapter was conducted by the USAF Airlift Center in October 1977. The IOT&E was documented in a MAC final report entitled "Initial Operational Test and Evaluation: Cargo Loader Adapter and Flying Tiger Adapter for Wide Bodied Aircraft."

Use of the Adapter poses some serious operational and safety problems. For example, due to the sweep of the B-747 wing, it is necessary to drive and

maneuver under the wing while aligning the adapted 40K with the side door. During the aligning procedure, the hand rails of the loader come very close to the aircraft wing tip and wing-mounted pylon. A similar problem arises with the unadapted 40Ks used to transport cargo to and from the adapter-equipped loader [33:79].

In addition, use of the Adapter would make the 40K useless for truck-bed-height loading such as is needed with the C-141 and the lower lobes of WBA (21:22; 33:79). Thus, in view of the age and expenditures already made to restore 40K loaders, the important question arises as to whether more dollars should be invested to attain a marginally effective added capability (33:79). The 40K Adapter just does not appear to be the answer to MAC's dual MHE problem, especially with the growing interest in WBA.

#### General Research Aim

Still, the DOD should make some decision concerning the 463L system. Should the decision be to continue to supplement the existing 463L system with commercial MHE or to begin a conversion to one standard MHE system that is compatible with both military aircraft and WBA? The answer can be obtained by performing a projected cost analysis on these two alternatives. If no analysis is accomplished, a specific decision may result in some unnecessary waste of MAC's funds. There is definitely a need for some type of cost analysis. The reader may probably realize that such a cost analysis would be very complex

and require substantial time and effort. The primary reason for this complexity is MAC's large number of MHE in its 463L system inventory. This MHE consists of 10K standard forklifts, 4K forklifts, 25K loaders, 40K loaders, 10K air-transportable forklifts, and 25K tactical loaders (35). Therefore, in order to simplify this situation in the presence of time constraints, the problem and the cost analysis in this research will be limited to 25K and 40K loaders. This limitation should not decrease the impact of the final solution. In other words, a cost study concerning only 25K and 40K loaders either existing in a future two-system environment or being replaced in the future by a single MHE system should still have a great effect on tomorrow's decisions in MAC.

Even if a cost analysis is performed and a solution to MAC's current MHE situation is recommended, other problems still exist. Probably the most crucial problem is related to the operations of the U.S. Army. In short, the problem arises during wartime. In the event of an emergency, a large percentage of all military cargo will be moved by air (12:19). Therefore, the 463L system will be used extensively. When the 463L pallet was initially developed, it was to be used for a terminal operation. Cargo would be transported to the aerial port of embarkation and then USAF personnel would unitize cargo on the 463L pallet. At the aerial port of debarkation (APOD),

USAF crews would depalletize the cargo from the 463L pallet and, if Army cargo was present, load the material on Army trucks. However, the current USAF policy is to allow the 463L pallets to be moved forward from the APOD. This policy presents a problem on account of the fact that the 88" by 108" pallet is only partially compatible with the existing Army cargo vehicles and MHE. "There are no forklift pockets in the pallet and, when loaded on the cargo deck of a vehicle, dunnage must be placed under the pallet to enable a forklift to pick it up [43:F-46]." In addition, "the 463L pallet cannot be handled as an outside load for helicopter lift due to structural limitations. The load must be reconstituted into sling loads or handled in another manner [43:F-46]." Thus, a 463L problem definitely exists which could prove to be very dangerous in a war situation (43:F-45 to F-46). Again, in order to not complicate the study, this research will focus only on MAC during peacetime.

#### Conclusion

In conclusion, although there are currently no recommended solutions to MAC's dual MHE system, the DOD is at least taking note of the situation. For example, MAC has recently developed a C-5 air-transportable dock (ATD).

The ATD was designed to provide a portable and rapid means of transferring vehicles, 463L pallets,

and aerial delivery system platform loads between the C-5 aircraft and surface transportation at forward area bases [26:1].

A C-5 ATD study group was formed at MAC to explore fresh and innovative ways to use the ATD, maximize its usage, and minimize time and use of MHE. Primary consideration was to discover the feasibility of interfacing the ATD with other military aircraft and civilian WBA. Preliminary evaluation as shown in "Operational Test and Evaluation: C-5 Air Transportable Dock Project Plan" indicates that C-135, C-141, DC-10, and B-747 aircraft can interface with the ATD (26:1). Thus, the DOD is becoming aware of the WBA's relationship to new military MHE. People are finally taking heed of the advice given in Patterson's 1966 thesis. They are starting to recognize that the design of cargo handling equipment required for the future depends largely on the design and capacity of tomorrow's aircraft. In essence, the purpose of the research documented in this paper is also based on Patterson's advice.

#### Research Objectives

A general objective of this research is to gather information critical to a cost analysis of MAC's alternatives of maintaining its dual system of cargo loaders or converting to a single system compatible with both military aircraft and civilian WBA. Specific objectives are:

1. To forecast the time period (year) in which U.S. civilian WBA will completely replace NBA.

2. To forecast the number of cargo loaders required for the year predicted in Objective 1 assuming that MAC maintains the 463L system and acquires commercially available loaders (e.g., Cochran 316A elevators) to accommodate U.S. civilian WBA.

3. To forecast the number of cargo loaders required for the year predicted in Objective 1 assuming that MAC acquires a newly-designed or commercially existing loader which is singularly capable of handling both military aircraft and U.S. civilian WBA.

4. To determine the total cost of both maintaining the 40K and 25K loaders of the 463L system and acquiring commercially available loaders to accommodate U.S. civilian WBA.

5. To determine the total cost of acquiring and maintaining a newly-designed or commercially existing cargo loader that singularly accommodates both military aircraft and U.S. civilian WBA.

6. If objective 5 proves to be unattainable, a subsequent objective would be to determine the maximum total cost at which the acquisition of a cargo loader (that singularly accommodates both military aircraft and U.S. civilian WBA) would be the cost-effective alternative over MAC's present dual system.

## Research Questions and Hypothesis

### Research Questions

The following two questions will be addressed in this research:

1. In what future year will wide-bodies completely replace narrow-bodies in U.S. flag carriers' medium- and long-range aircraft?

2. How will a total substitution of wide-bodies for narrow-bodies in U.S. flag carriers' medium and long-range aircraft, along with changes in cargo activity, alter MAC's future loader requirements?

### Research Hypothesis

The answers to the two preceding research questions will be used in addressing the following hypothesis:

It is more cost effective for MAC to acquire a single cargo loader capable of interfacing with both military cargo aircraft and civilian WBA than to continue maintaining a dual system consisting of K-loaders servicing military aircraft and commercial loaders (e.g., Cochran 316A elevators) handling civilian WBA.

## CHAPTER II

### METHODOLOGY

The future of the commercial airline industry, like that of any other U.S. business, is filled with uncertainties. Various uncertainties of the aircraft market might include the future technological advance in aircraft design, the future availability of aircraft fuel, and the future competition of other modes of transportation. Even with these uncertainties, the reader should recognize that the future of the airline industry will have a direct effect on the number and aircraft type of Category B missions flown by MAC over the next two decades. As a result, the future of Category B missions is also very unpredictable today. It is the future uncertainty of these missions which makes MAC's decision of maintaining a dual MHE system versus converting to a single system a difficult one.

The methodology described in this chapter provides a quantitative framework through which MAC can view its present alternatives with regard to the MHE problem. In reference to the research objectives, the major thrust of this research involves two goals: (1) to present MAC with a forecast of the future U.S. WBA and NBA market (Research

Objective 1) and (2) to furnish MAC with a cost analysis of its options of maintaining its dual system of cargo loaders or converting to a single system compatible with both military aircraft and civilian WBA (Research Objectives 2 through 6). The procedures which were utilized in achieving these two goals consisted of three phases. Phase I involved a forecast of the U.S. wide-body and narrow-body market. This phase provided a projection of the future year in which U.S. WBA would completely replace U.S. NBA. In effect, since there would be no NBA existing in the inventory, this prediction would allow MAC to determine when a total reliance on WBA would occur with respect to supporting Category B missions. In other words, Research Question 1 was then answered. Phase II of this methodology involved two steps: (1) to develop a forecast of the amount of cargo transported within MAC channels from the present until the year when NBA are entirely replaced by WBA and (2) to determine the number of loaders required by MAC, in the year in which narrow-body replacement is completed, for both alternatives of maintaining a dual MHE system and converting to a single system. In answering Research Question 2, Phase II enabled MAC to determine how much overall loader requirements would be altered by the forecasted substitution of U.S. civilian WBA for NBA. The final phase, Phase III, involved the cost analysis of MAC's two alternatives.

A present value analysis was performed so that future costs of maintaining the present dual loader system could be compared with similar costs of converting to a single loader system. In this way, the research hypothesis was addressed and MAC should be able to ascertain which alternative would be more cost effective. Thus, this research was conducted to assist MAC in making a cost-effective decision concerning its MHE situation.

#### Phase I

As stated previously, Phase I addressed Research Question 1 and entailed a market forecast of the future substitution of U.S. civilian wide-bodies for narrow-bodies. In general, the technique used in this phase simply consisted of a technological forecast of the U.S. wide-body and narrow-body market. In essence, the WBA and NBA projection provided by Phase I forms the foundation for this whole research study. Again, this foundation is a direct result of MAC's dependence on the WBA and NBA market.

#### Description of the Populations

The three variables or populations utilized in this phase were the amount of revenue tonnage (Rev-Tons) transported by wide-bodies in U.S. flag carriers' medium- and long-range aircraft, the amount of Rev-Tons transported by narrow-bodies in U.S. flag carrier's long-range

aircraft, and time. Specifically, the dependent variables were the amount of Rev-Tons flown by WBA and NBA while the independent variable was time. With respect to these variables, the corresponding universes were the physical weight of the passengers, baggage, freight, express, and mail transported by wide-bodies and narrow-bodies, and again time.

First, in a breakdown of the independent variables, the population of Rev-Tons carried by WBA consisted of passenger revenue tons (Prev-Tons) and cargo revenue tons (Crev-Tons) moved by B-747, B-757, B-767, DC-10, and L-1011 aircraft. With respect to tonnage, the following definitions are presented:

Passenger revenue ton--one ton (2,000 pounds) of passenger weight (including all baggage) transported in revenue service by either WBA or NBA.

Cargo revenue ton--one ton (2,000 pounds) of revenue traffic weight, other than revenue passenger weight, transported by either WBA or NBA (includes freight, express, mail, and excess baggage).

Revenue ton--one ton (2,000 pounds) of revenue weight (passenger or traffic) transported by either WBA or NBA (11:617,620).

The reader should note that the Rev-Tons used in this analysis referred to any tonnage moved in the scheduled domestic and international/territorial operations of trunk (passenger and/or cargo) and all-cargo carriers. In relation to the wide-bodies carrying the Rev-Tons, all aircraft included here were long-range WBA except the new B-767, which was an intermediate or medium-range wide-body (14).

An assumption was made that the B-767 would also be contracted by MAC in a Category B capacity (36). Second, the other independent variable, the amount of Rev-Tons transported by NBA, would be similarly broken down. This population consisted of Prev-Tons and Crev-Tons moved by B-707 and DC-8 aircraft. It should be indicated that these narrow-bodies were simply long-range passenger aircraft. A final point should be made, however, that this phase did consider both passenger and cargo aircraft. This consideration was based on the fact that MAC contracts both types for Category B missions (19).

#### Data Collection

In developing any kind of realistic future forecast, the researcher must be able to obtain complete and accurate historical data. Without valid past data, there is no point in even attempting to make a future projection. Thus, in order to present MAC with an accurate picture of NBA replacement by WBA, valid historical information reflecting this technological transition (e.g., past Rev-Tons flown by wide-bodies and narrow-bodies<sup>1</sup>) had to

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<sup>1</sup>One should recognize that the number of WBA and NBA in inventory would not provide MAC with a "true" representation of the replacement process. This misrepresentation would be a result of the fact that a wide-body and a narrow-body have different load capacities. Thus, Rev-Tons would be more helpful in this analysis.

be obtained. It is noted that this revenue tonnage data were not directly acquired since other pertinent data had to be manipulated so that data concerning Rev-Tons could actually be collected. This "intermediate" census data were found in a document entitled Aircraft Operating Cost and Performance Report published by the Civil Aeronautics Board (CAB). The CAB report at this time and place was only available for calendar years 1970 through 1975. It was assumed that the data contained in this publication had been collected and compiled accurately and completely.

With regard to the manipulation of the data contained in the CAB reports, the following equations were employed:

Prev-Tons = [Total Airborne Hours (all revenue services)]

x [Average Airborne Speed (all revenue services)]

x [Average Revenue Passengers per Aircraft Mile (scheduled revenue service)]

x [Passenger Weight Standard] (Eq. 1)

$\text{Crev-Tons} = [\text{Total Airborne Hours (all revenue services)}]$

$\times [\text{Average Airborne Speed (all revenue services)}]$

$\times [\text{Average Revenue Tons per Aircraft Mile (scheduled revenue service)}]$  (Eq. 2)

$\text{Rev-Tons} = \text{Prev-Tons} + \text{Crev-Tons},$  (Eq. 3)

where

Total Airborne Hours (all revenue services) is the airborne hours (in revenue service) which is "computed from the moment an aircraft leaves the ground until it touches the ground at the next point of landing [10:121],"

Average Airborne Speed (all revenue services) is the average speed of an aircraft while airborne (in revenue service),

Average Revenue Passengers per Aircraft Mile (scheduled revenue service) is the average number of passengers transported (in scheduled revenue service) per mile flown,

Average Revenue Tons per Aircraft Mile (scheduled revenue service) is the average tons of

traffic transported (in scheduled revenue service) per mile flown, and

Passenger Weight Standard is 0.1 for both domestic and international/territorial operations (passenger weight is defined as 200 pounds; thus, the standard equals 200 pounds divided by 2,000 pounds per ton) (10:110; 11:617,620,621).

In view of the form of the information provided by the CAB, Rev-Tons were calculated for the specific types of WBA and NBA in inventory for the years 1970 through 1975. A total annual Rev-Tons for wide-bodies and narrow-bodies was then determined by summing the appropriate aircraft Rev-Tons in a certain year. The reader must note that data used in this phase only pertained to the certificated route air carriers<sup>2</sup> (often referred to as "scheduled airlines"). The CAB reports did not provide the necessary information to similarly compute Rev-Tons for the supplemental air carriers<sup>3</sup> (often referred to as "nonscheduled

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<sup>2</sup>A certificated route air carrier is "one of a class of air carriers holding certificates of public convenience and necessity, issued by the CAB, authorizing the performance of scheduled air transportation over specified routes and a limited amount of nonscheduled operations [11:618]."

<sup>3</sup>A supplemental air carrier is "one of a class of air carriers now holding certificates, issued by the CAB, authorizing them to perform passenger and cargo charter services supplementing the scheduled service of the certificated route air carriers [11:621]."

airlines"). However, since the supplemental carriers move a very small portion of the total tonnage carried by certificated airlines each year, this lack of information had a minimal effect on the study.

#### Substitution Rate Forecast

There are numerous techniques available for predicting the future of technology. With respect to answering Research Question 1, the substitution rate forecast seemed to be an appropriate technique to utilize in this case. The substitution rate forecast is a type of trend extrapolation, which is based on a little different approach than that employed for single trend extrapolation, growth analogy, or correlation analysis. The substitution effect or phenomenon is premised on the tenet that one product or technology which displays a relative increase in performance over an older, established product or technology will ultimately substitute for that product or technology of secondary importance. The relative increase in performance is the vital factor in the substitution process. Therefore, if WBA and NBA could be thought of as two technologies substituting for one another, then this technique is very applicable. A classic example of the substitution phenomenon is the one of steam for sail as a method of motive power for

commercial ships (see Figures 9 and 10). Figure 10 represents a substitution rate forecast done in 1830 (5:6-41 to 6-42; 25:69-72).

The substitution rate model which is most often used was developed by Fisher and Pry in 1971. The substitution forecast progresses at rates specified by the following equation:

$$f = 1/2[1 + \text{TANH } z(t - t_0)] \quad (\text{Eq. 4})$$

where

$f$  is the fraction of take-over by the new technology (e.g., WBA) in year  $t$ ,  
 $z$  is one half of the initial annual exponential take-over rate (IAETR),  
 $t_0$  is the year in which  $f$  equals 0.5, and

IAETR is an expression of each yearly increase of the new technology as a percentage of the preceeding year's percent of total usage.  
(Note: if more than one IAETR is available, then  $z$  should be computed for each one and then averaged for use in the formula)  
(5:6-41).

In this research the forecast began with the discovery that a new technology was really replacing an

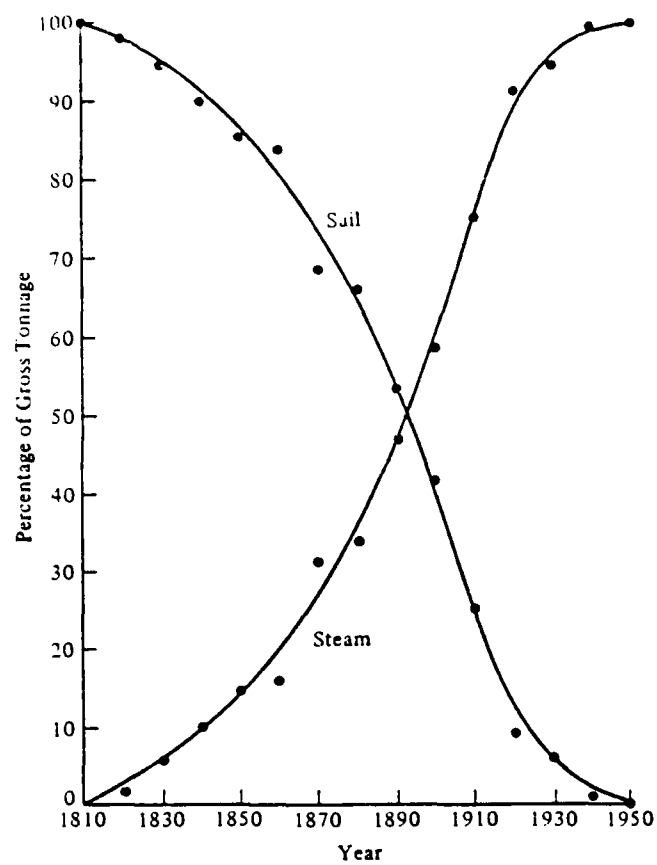


Fig. 9. Substitution of Steam for Sail (1810-1950) (25:72)

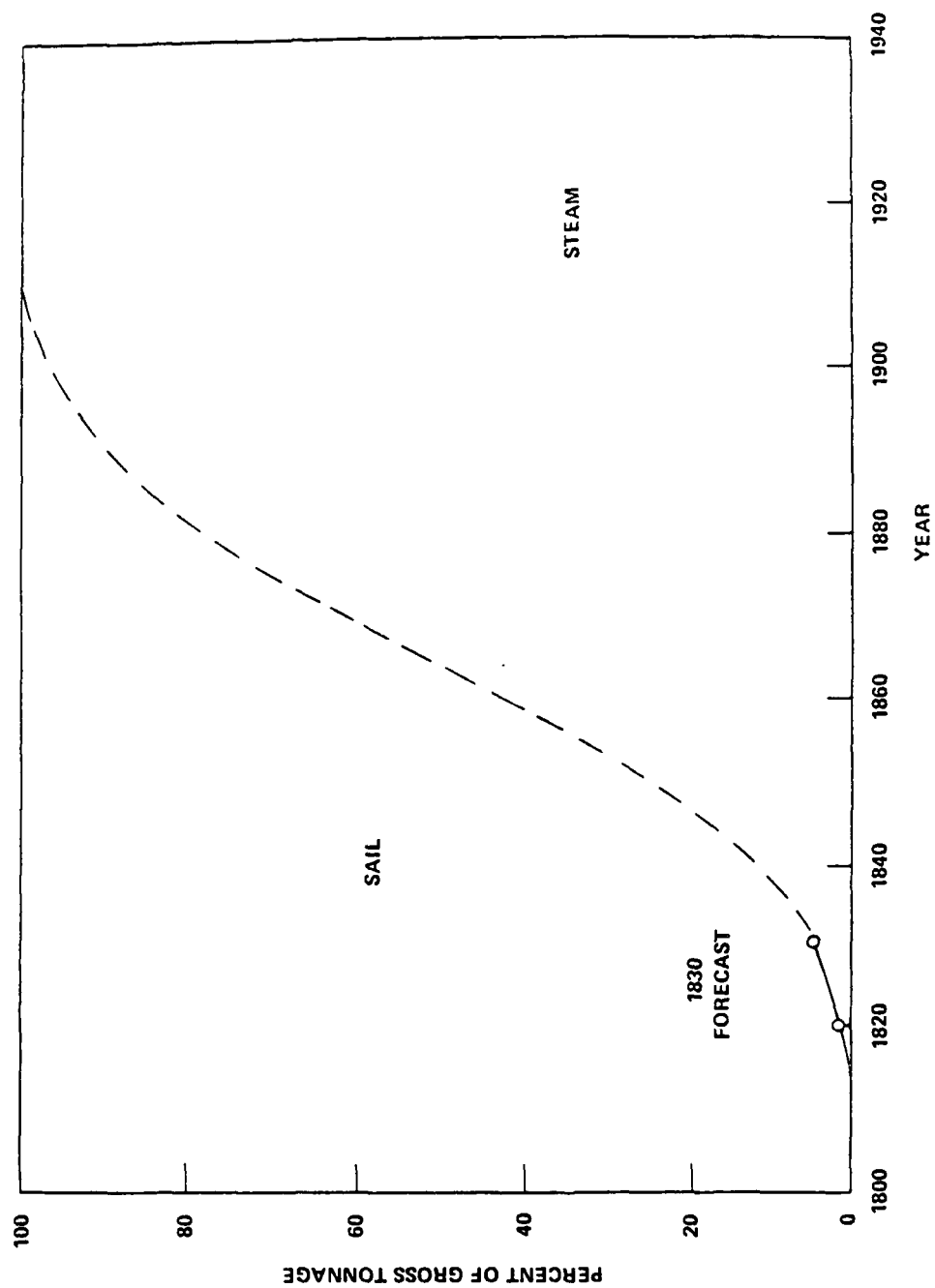


Fig. 10. Substitution of Steam for Sail (1830 Forecast) (5:6-48)

older technology. The discovery that wide-bodies were replacing narrow-bodies had been initially made in the analysis of other pieces of research (see Chapter I, Literature Review). Having made this finding, time series data (reflecting a measurement term which properly defined the portion of total usage of technology<sup>4</sup>) were then manipulated to establish the IAETR and to predict  $t_0$  (the year in which 50 percent take-over would occur) on the foundation of Equation 4. Equation 4 was consequently used to forecast the times (years) when various percentages of take-over would occur (5:6-41 to 6-42). In this study, it was desired to predict the year in which U.S. civilian WBA would completely replace NBA with respect to transporting Rev-Tons ( $t_c$ ). This forecast, in essence, would answer Research Question 1. Thus, in order to insure complete replacement, a criterion of 99.95 percent substitution was the desired prediction.

In forecasting the rate of take-over, the characteristic S-curves (substitution curves which are commonly referred to as logistic curves) were produced. Both S-curves (for the new and old technology) could be derived

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<sup>4</sup>As an informal rule for selecting a measurement term to use in a substitution rate forecast, one should choose "a parameter that reflects the basic or primary function that the old and new technologies are performing in that particular usage [5:6-42]." Therefore, in this case Rev-Tons was an appropriate parameter.

in actuality from Equation 4. The curves appear as shown in Figure 11:

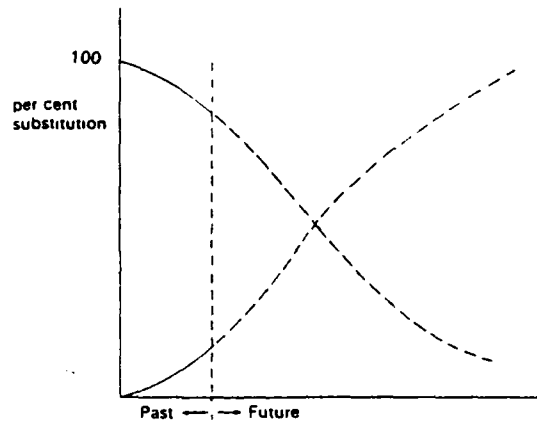


Fig. 11. Substitution Curves (23:203)

With respect to the formulation of these substitution curves, one should be aware of two major points. The first point is that two basic assumptions are made in the application of this technique. These assumptions include: (1) the old and new technologies are direct substitutes for one another (e.g., Rev-Tons carried by WBA is a direct substitute for Rev-Tons carried by NBA) and (2) once the substitution of one technology for another has started, it will unyieldingly continue to completion (e.g., WBA will eventually replace NBA in relation to being a transporter of Rev-Tons). A second point to realize is that as time

passes and additional information on the real take-over rate becomes obtainable, errors may be seen in the original forecast. New projections may then be made by redoing the computations using the new data points (see Figure 12 for revision of 1830 substitution forecast of steam for sail) (5:6-41 to 6:46; 23:205-206; 25:69-78).

#### Evaluation of the Substitution Rate Forecast

In time series applications, one frequently wishes to predict an individual response. In this research there was a desire to determine how accurate and important the projected take-over of WBA for NBA really was. Thus, the concept of prediction intervals was utilized in order to predict from a time series analysis (substitution rate forecast).

The formation of a prediction interval in this study was a slight bit more complicated than formation of intervals in normal regression cases. The complication of this interval was simply a result of the necessary transformation of a nonlinear model to a linear one. In other words, it was essential to transform one of the substitution curves to a linear function. Since both curves (the new technology curve--WBA, and the old technology curve--NBA) relate to the same situation or take-over, a prediction interval only had to be formed for one. Therefore,

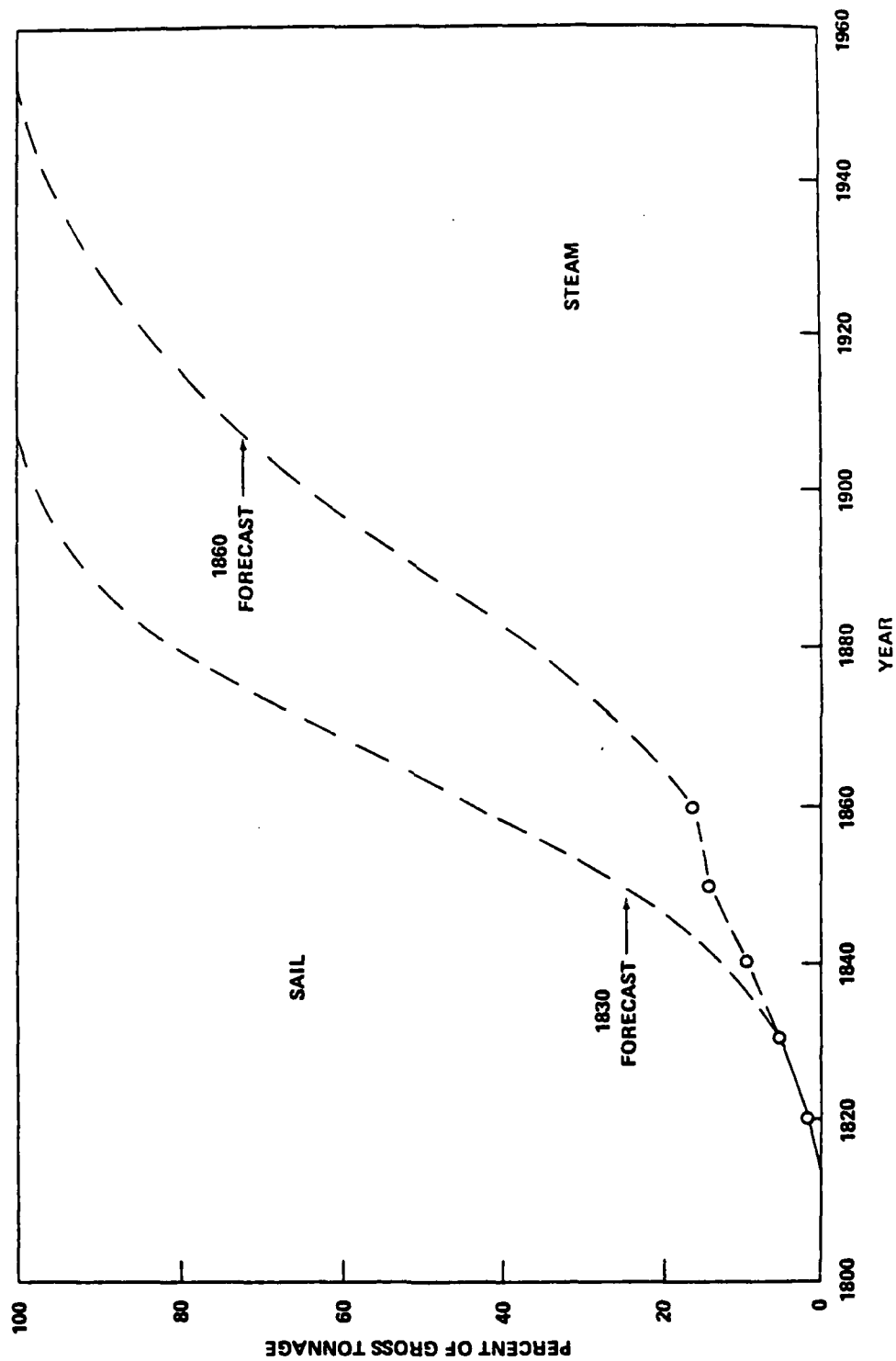


Fig. 12. Substitution of Steam for Sail (1830 and 1860 Forecasts) (5:6-50)

it was decided that the interval would be based on the NBA substitution curve. The equation for this curve is as follows:

$$y = 1 - [1/(a + bc^t)] \quad (\text{Eq. 5})$$

where

y is the fraction of Rev-Tons transported by NBA in the year t (which will be eventually transported by WBA), and

a, b, and c are all constants.

Through a derivation (see Appendix A), it can be shown that:

$$w = u + vt \quad (\text{Eq. 6})$$

where

$$w = \text{LOG } y/(1-y),$$

$$u = \text{LOG } b, \text{ and}$$

$$v = \text{LOG } c \quad (3).$$

As a result, in this case the appropriate equation for a two-sided prediction interval with confidence  $1-\alpha$  (0.8)<sup>5</sup> was:

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<sup>5</sup>Since the future is so unpredictable, this research team felt that a more conservative level of confidence (e.g., 80 percent) should be used in this study.

$$w_{t_c} - t(1 - \alpha/2; n-2) s(d_{t_c}) \leq w_{t_c}^{\hat{}} \leq w_{t_c} + t(1 - \alpha/2; n-2) s(d_{t_c}) \quad (29:468-472) \quad (\text{Eq.7})$$

where

$w_{t_c}$  is the logarithm of the projected  $y/(1-y)$  in period  $t_c$  [computed by MLREG, a "canned" Fortran program entitled Multiple Linear Regression (31:1-3)],

$t_c$  is the (coded) year in which  $y$  is projected by the substitution rate forecast to be 0.05 percent,

$t(1-\alpha/2; n-2)$  is a t-statistic with probability of  $1-\alpha/2$  ( $\alpha = 0.2$ ) and  $n-2$  degrees of freedom, found in basic statistical tables (4:81-82),

$n$  is the number of observations (in this case,  $n = 6$ ),

$s(d_{t_c})$  is the standard deviation of the individual response [an estimator of the true standard deviation computed by MLREG (31:1-3)], and

$w_{t_c}^{\hat{}}$  is the logarithm of the true  $y/(1-y)$  in period  $t_c$ .

So, using the predicted  $w_{t_c}$  and  $s(d_{t_c})$  produced by MLREG, a "logarithmic" prediction interval was obtained. Therefore, by taking the antilog and manipulating the

inequality  $[\text{LOG } y/(1-y) \rightarrow y]$ , the correct prediction interval was secured. This interval provided a means to determine the degree of importance of the projected take-over as indicated by the substitution rate forecast.

### Phase II

As previously indicated, Phase II addressed Research Question 2 and entailed two principal steps. These steps included (1) a forecast of the amount of cargo flown within MAC channels from the present time until the year in which U.S. civilian NBA are entirely replaced by WBA ( $t_c$ : see Phase I, Substitution Rate Forecast) and (2) a determination of the number of cargo loaders required by MAC in the year  $t_c$  for both alternatives of maintaining a dual MHE system and converting to a single system. This phase is in reality a building block for the cost analysis in Phase III.

#### Aggregate Forecast of MAC Cargo Activity

Description of the Populations. The three variables or populations being utilized in this phase were the total amount of cargo tonnage moved within MAC avenues [e.g., tonnage flown by military aircraft and by U.S. civilian WBA and NBA (Category B capacity)], the amount of cargo tonnage moved within MAC channels by U.S. civilian WBA (Category B capacity), and time. Specifically,

the dependent variables were the total amount of cargo transported within MAC and the amount of cargo transported within MAC by WBA while the independent variable was time. With respect to these variables, the corresponding universes were the physical weight of all cargo flown within MAC, the physical weight of the cargo flown within MAC by WBA, and again time.

First, in a breakdown of the independent variables, the population of total cargo tonnage flown consisted of the total amount of cargo transported by B-747, B-757, B-767, DC-10, L-1011, B-707, and DC-8 aircraft and by all aircraft in MAC's inventory. Second, the other independent variable, the cargo tonnage flown by WBA, could be similarly broken down. This population consisted of the amount of cargo moved by B-747, B-757, B-767, DC-10, and L-1011 aircraft. With regard to the wide-bodies, all aircraft included here were long-range WBA except the new B-767, which was an intermediate or medium-range wide-body (14). An assumption was made that the new B-767 would also be contracted by MAC in a Category B capacity (36).

Data Collection. As in the development of the technological forecast in Phase I, complete and accurate historical data had to be obtained for the forecast in this phase. Thus, in order to determine MAC's loader

requirements in the future, valid past information concerning cargo activity had to be acquired. These data were found in the MAC 7107 Report, the Monthly Station Traffic Handling Report, which was available at MAC/TRPP (Transportation Plans and Programs Division at MAC Headquarters, Scott AFB). Specifically, the 7107 report contained the amount of cargo flown in (terminating) and flown out (originating) at each MAC station or base. MAC/TRPP possessed copies of this report for the past six years. Therefore, census statistics pertaining to the amount of cargo transported within MAC channels was only acquired for the years 1974 through 1979. It was assumed that the data contained in these reports had been collected and compiled accurately and completely.

In relation to using the 7107 reports for the forecast of Phase II, these data had to be grouped and summarized. In other words, first, the total amount of cargo (total tons of cargo and mail) handled in a specific month at a specific base was tabulated by traffic category and type of aircraft used. In this case, the traffic categories included ASIF (cargo financed by the Airlift Service Industrial Fund) and Non-ASIF (cargo not financed by the Airlift Service Industrial Fund--cargo funded by MAC) while the types of aircraft used were comprised of military and commercial (civilian). The

reader should note that this monthly tabulation of total tonnage was only performed for MAC's twenty major aerial ports (19). A list of these aerial ports is found in Table 1. After tabulating these tonnages for each base, monthly totals of all twenty ports were then obtained for the four possible manipulations of cargo (e.g., cargo transported by military ASIF, military Non-ASIF, Civilian ASIF, and Civilian Non-ASIF aircraft). Later, however, a decision was made to regroup the data. The new groupings which were used included: (1) total tonnage flown, (2) tonnage flown by military and civilian Non-ASIF aircraft, and (3) tonnage flown by civilian ASIF aircraft. This new breakdown was a direct result of insight that was provided by people at MAC Headquarters. Specifically, personnel at MAC/TRPP informed this research team that civilian Non-ASIF aircraft typically involved NBA while civilian ASIF involved WBA. Thus, the basis for the new second grouping was that this tonnage was handled solely by K-loaders. On the other hand, the rationale for the third grouping was simply that this tonnage had to be manipulated by the dual loader system (e.g., only tonnage handled by elevator loaders) (19). One should also recognize that the sum of these two groupings logically equalled the first. This first grouping reflected total cargo activity within MAC, or in other words, represented total tonnage handled by 463L equipment. Having

Table 1  
MAC'S MAJOR AERIAL PORTS

<u>21st Air Force</u>	<u>22nd Air Force</u>
Adana/Incirlik	Clark
Charleston	Kadena
Dover	Elmendorf
Rhein-Main	Hickam
Howard	Yokota
Mildenhall	Osan
Norfolk	Norton
Ramstein	Travis
Torreon	McChord
McGuire	Andersen

determined the monthly totals for these three groupings over the past six years, the final task in this data collection was to calculate an average monthly tonnage for each year by grouping. In this way, the data were consistent with: (1) the original statistics contained in the 7107 reports (e.g., tonnages were expressed in monthly amounts<sup>6</sup>, and (2) the methodology posed in Phase I (e.g., average tonnages flown monthly corresponded to specific years). In addition, the data were in a usable form for easy development of an aggregate forecast of cargo activity within MAC.

Linear Trend Forecast. The time series analysis in this phase involved a utilization of the linear trend model. A linear trend is one where the trend is constant from one period to another. The application of this model to the aggregate cargo situation seemed very reasonable. This reasonable application was first based on the intuition that a plot of the historical data obtained from MAC 7107 Reports would display a trend characteristic of linearity. Second, the linear trend model is very easy to use. Considering the fact that MAC might sometime desire

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<sup>6</sup>As will be discussed later in the methodology, loader requirements for MAC are based on monthly tonnage activity. Therefore, aggregate monthly averages were essential to this phase of research.

to update the results of this research, the model appeared indeed to be applicable.

In equation form, the linear trend model can simply be expressed as:

$$T_t = b_0 + b_1 X_t \quad (\text{Eq. 8})$$

where

$T_t$  is the trend value for period  $t$ ,

$X_t$  represents a numerical code denoting period  $t$ , ( $t = 1, \dots, n$ ), and

$b_0$  and  $b_1$  are the Y-intercept and the slope of the trend line, respectively (29:615).

This equation is referred to as the linear trend function which is identical to an estimator for the simple linear regression function. The simple linear regression function can be expressed like the following:

$$E(Y_i) = \beta_0 + \beta_1 X_i \quad (\text{Eq. 9})$$

where

$E(Y_i)$  is the expected value of the response in the  $i$ th observation,

$\beta_0$  and  $\beta_1$  are the true Y-intercept and true slope of the regression line, respectively, and

$X_i$  is the value of the independent variable in the  $i$ th observation, assumed to be a known constant (29:440).

This regression function is based on the simple linear regression model which is defined as:

$$Y_i = \beta_0 + \beta_1 X_i + \epsilon_i \quad (\text{Eq. 10})$$

where

$\beta_0 + \beta_1 X_i$  is the line of statistical relationship component, and

$\epsilon_i$  is the random scatter component (29:439).

Therefore, in using the linear trend model, one is actually employing simple linear regression.

In relation to this phase of research, a linear regression was easily built from observations of the amount of cargo tonnage transported within MAC channels over time. In short, the coded independent variable  $X_t$  represented the years from 1971 to  $t_c$ . For example, 1971 was denoted by the time period  $X_1 = 1$ . In addition,  $t_c$  (the predicted year in which WBA would completely substitute for NBA) was denoted by  $X_{t_c} = t_c - 1970$ . One should note that the relevant range of  $X_t$  for the historical data used in this study was 4 through 9 (1974 through 1979). In comparison to the independent variable,  $T_t$ , the dependent variable, represented the average total

cargo tonnage flown monthly or the average cargo tonnage flown monthly by U.S. civilian ASIF aircraft (WBA) in the corresponding time period  $t$ . Ultimately, with the use of these variables, two estimated regression lines could be developed. One line pertained to the total cargo tonnage flown and the other reflected the cargo tonnage flown by WBA. The total tonnage regression line was denoted by the equation:

$$T_t = a + bX_t \quad (\text{Eq. 11})$$

where

$a$  and  $b$  are the estimated intercept and slope coefficients, respectively.

In addition, the WBA tonnage regression line was denoted by the equation:

$$T_t = c + dX_t \quad (\text{Eq. 12})$$

where

$c$  and  $d$  are the estimated intercept and slope coefficients, respectively.

These linear regression lines were derived by using MLREG (31:1-3). In essence, the historical data which had been

extracted from MAC 7107 Reports for the years 1974 through 1979 were manipulated by this "canned" program.

Finally, after the development of these regression lines by the computer, future amounts of cargo tonnage flown monthly were then calculated from the two estimated functions. These calculations were simply accomplished by solving the two estimated regression functions for the response  $T_t$  with a given future  $X_t$ .<sup>7</sup> The reader should note that, if required, the future tonnage flown monthly by military and civilian Non-ASIF aircraft (NBA) was determined by subtracting the future WBA tonnage from the future total tonnage. Thus, it was not necessary to derive a regression line for the cargo tonnage flown by this grouping.

Evaluation of the Linear Trend Forecast. A criteria test in this phase would normally consist of two parts. The first part would involve an overall evaluation of model aptness. The second part would involve the construction of a prediction interval for the individual response. However, as will be explained in Chapter III,

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<sup>7</sup> A point should be made that the only response  $T_t$  needed in this phase was the one associated with  $X_{t_c}$ . The reason for this single response is that the determination of MAC loader requirements in Phase II (to be discussed) was based on the year  $t_c$ . Still, other values of  $X_t$  (corresponding to the present through  $t_c$ ) were used in Phase III.

an evaluation of model aptness was not performed in this study. Thus, the criteria test only consisted of a prediction interval formulation.

In time series applications, one frequently wishes to predict an individual response. In this research there was a desire to determine how accurate and important the projected cargo tonnages really were. Thus, the concept of prediction intervals was utilized for the ability to predict from a time series analysis (linear trend forecast).

In this case the appropriate equation for a two-sided prediction interval with confidence coefficient  $1 - \alpha$  (0.8) was:

$$T_{t_c} - t(1 - \alpha/2; n-2) s(d_{t_c}) \leq T'_{t_c} \leq T_{t_c} + t(1 - \alpha/2; n-2) s(d_{t_c}) \quad (\text{Eq. 13})$$

(29:468-472)

where

$T_{t_c}$  is the projected cargo tonnage (in average tons per month) flown in period  $t_c$  [computed by MLREG (31:1-3)],

$t_c$  is the (coded) year in which WBA are predicted to completely replace NBA,

$t(1 - \alpha/2; n-2)$  is a t-statistic with probability of  
 $1 - \alpha/2$  ( $\alpha = 0.2$ ) and  $n-2$  degrees of  
freedom found in basic statistical tables  
(4:81-82),

$n$  is the number of observations (in this case,  
 $n=6$ ),

$s(d_{t_c})$  is the standard deviation of the individual  
response [an estimator of the true standard  
deviation computed by MLREG (31:1-3)], and  
 $T_{t_c}$  is the true cargo tonnage (in average tons  
per month) flown in period  $t_c$ .

Thus, using the predicted  $T_{t_c}$  and  $s(d_{t_c})$  produced by MLREG,  
prediction intervals for total tonnage and WBA tonnage  
(corresponding to the two estimated regression lines) were  
obtained. These intervals provided a means to determine  
the degree of importance of the projected cargo tonnages  
as indicated by the linear trend forecast.

#### Aggregate Loader Requirements

The loader requirements of the twenty USAF MAC  
bases under consideration were determined as a function of  
the loader inventory as of 1979 and the number of addi-  
tional loaders required to satisfy projected increases in  
cargo activity through the year  $t_c$ . Other factors  
affecting loader requirements, such as terminal

classifications and individual USAF base requirements for War Readiness Materials (WRM), were assumed to remain constant over the period of this analysis. Loader inventory information and projected cargo tonnages for the twenty MAC bases were treated on the aggregate level. Thus, a projected aggregate inventory requirement of loaders for the twenty MAC bases was obtained and the concern about distribution of these loaders among air bases was avoided.

Dual Loader System. The dual loader system which MAC presently maintains consists of 25K loaders, 40K loaders, and Cochran elevators. As mentioned previously, K-loaders service NBA and while the Cochran elevators interface with WBA, the K-loaders are still necessary to transport cargo from the terminal to the elevator. Essentially, K-loaders are required to transport all cargo and the Cochran elevator is necessary only to lift cargo from the K-loader to the WBA cargo hold. Therefore, K-loader requirements of the dual loader system were based on the total cargo tonnage projection for the year  $t_c$  and Cochran elevator requirements of the dual loader system were based on that portion of the total cargo projection of year  $t_c$  that was transported by WBA.

The determination of the number of 40K loaders required for year  $t_c$  was based on the inventory of 40K

loaders as of 1979, and the number of 40K loaders justified by the projected increase in average monthly cargo tonnage between the years 1979 and  $t_c$ . The representative equation is as follows: 40K loader requirement for year  $t_c$  = number of 40K loaders in the 1979 inventory + number of 40K loaders required to accommodate the projected cargo tonnage increase between 1979 and year  $t_c$ . The knowledge of 1979 inventory levels of 40K loaders was obtained from MAC/TRPP. Cargo tonnage data for the year 1979 was obtained from the MAC 7107 Report. The total cargo tonnage projection for year  $t_c$  was obtained via the regression line developed in Phase I of this analysis (see Appendix H). The MAC Table of Allowances (Tech Order 36A-1-1301) was used to translate the twenty MAC bases' average monthly cargo tonnages into 40K loader requirements. The Table of Allowances for average monthly cargo tonnages is shown in Table 2.

In more detail, the 40K loader requirement due to the projected increase in cargo tonnage transport was determined as follows. The aggregate monthly cargo tonnages for years 1979 and  $t_c$  were divided by the number of air bases involved in the analysis (this number was twenty) to obtain the average monthly cargo tonnages per air base for years 1979 and  $t_c$ . The Table of Allowances was then applied to these figures to obtain average air base loader requirements for years 1979 and  $t_c$  and the

Table 2  
ALLOWANCES FOR K-LOADERS BASED ON CARGO TONNAGE

Number of Loaders	Loader Type	Average Monthly Cargo Tonnes (Tons/Month)
1	25K	0 - 500
2	25K	500 - 1,000
2	40K	1,000 - 1,500
4	40K	1,500 - 2,500
5	40K	2,500 - 3,500
6	40K	3,500 - 4,500
7	40K	4,500 - 5,500
9	40K	5,500 - 6,500
10	40K	6,500 - 7,500
12	40K	7,500 - 9,500
14	40K	9,500 - 11,500
16	40K	11,500 - 13,500
18	40K	13,500 - 15,500

difference of these two loader requirements was determined. Finally, this difference was multiplied by the number of air bases involved in this analysis to obtain the aggregate 40K loader requirement that was associated with the projected increase in cargo tonnage from the year 1979 to year  $t_c$ . The expanded equation that was used to determine the 40K loader requirement for year  $t_c$  is presented in Figure 13.

The requirement for 25K loaders was assumed to be constant and satisfied for the dual loader system. The unchanging or constant requirement is a valid assumption in as much as any predicted increases in cargo tonnage that might have affected 25K loader requirements of the dual system were translated into 40K loader requirements. Research found that not only are actual 25K loader requirements satisfied, but that as of January 1980, there was an excess inventory of 25K loaders in MAC (17). It was further discovered that this inventory of 25K loaders was maintained in part to substitute for 25K tactical loaders in the event that the USAF was placed on a war footing (17). In this light, the researchers realized that an inventory of 25K loaders would be maintained by MAC whether the present dual loader system was maintained or not. That is, even if the single loader system were implemented, a force of 25K loaders would be kept in operation for potential use in the tactical role. A final

$$\begin{aligned}
 & \text{Number of 40K Loaders Required for Year } t_c \\
 & = \left[ \text{Number of 40K Loaders in 1979 Inventory} \right] + \\
 & + 20 \times \left[ \text{T.A.} \left( \frac{\text{Aggregate Monthly Cargo Tonnage for Year } t_c}{20} \right) - \text{T.A.} \left( \frac{\text{Aggregate Monthly Cargo Tonnage for Year 1979}}{20} \right) \right]
 \end{aligned}
 \tag{Eq. 14}$$

Where T.A. indicates application of MAC's Table of Allowances

Figure 13. 40K Loader Requirement Equation

assumption was that similar inventories of 25K loaders which would accommodate similar annual cargo tonnages would be maintained in either the dual loader or single loader system. The result of this assumption is that consideration of the 25K loader may be dropped from the economic analysis of the two cargo loader systems.

No formal justification exists for allocating Cochran elevators other than the individual air base need to service WBA. That is, no WRM requirements have been established for these elevators and terminal classifications do not apply (17). For this reason, the elevator requirement was determined solely from the projection of aggregate cargo tonnages of WBA into the year  $t_c$ . The prediction of WBA cargo tonnages was calculated from the regression equation that was developed for such purposes in the first part of this phase. An assumption made when determining the elevator requirement was that the Table of Allowances for K-loaders would be appropriate to translate cargo tonnages into an elevator requirement. That is, the translation of tonnage into a need for a number of 40K loaders would reflect a need for a similar number of elevators. Considering that K-loaders transport cargo from the terminals to elevators which then load the cargo into WBA and that K-loaders are such major elements of the WBA loading operation, this assumption does not appear inappropriate.

The determination of the requirement of Cochran elevators consisted of applying the Table of Allowances to the average monthly WBA cargo tonnage per air base for year  $t_c$ . This elevator requirement multiplied by the number of air bases that accommodated WBA determined the aggregate elevator requirement for MAC for year  $t_c$ . The number of air bases which accommodate WBA was obtained from the MAC 7107 Report. The equation representing this determination of the requirement for Cochran elevators is shown in Figure 14.

Single Loader System. The determination of the number of loaders required for the single loader system for the year  $t_c$  was based on the cargo transport capabilities of the FMC mobile cargo loader. The FMC loader is one of several loaders being considered for acquisition by MAC (37) and it was assumed in this analysis that the FMC loader is representative of the type of cargo loader MAC might choose to purchase.

Of course, no formal Table of Allowances for the FMC loader exists in the USAF and this presented a problem for determining the single loader system requirement for year  $t_c$ . The solution to this problem was to relate the FMC loader's cargo transport capability to that of the 40K loader, and then translate the projected requirement of 40K loaders for year  $t_c$  into an equivalent FMC loader requirement.

$$\begin{array}{c} \text{Number of Elevators} \\ \text{Required for} \\ \text{Year } t_c \end{array} = \frac{\left[ \begin{array}{c} \text{Number of Air Bases} \\ \text{Accommodating WBA} \end{array} \right]}{\left[ \begin{array}{c} \text{T.A.} \left( \frac{\text{Aggregate Monthly} \\ \text{WBA-Cargo} \\ \text{Tonnage for Year } t_c}{\text{Number of Air Bases} \\ \text{Accommodating WBA}} \right) \end{array} \right]}$$

(Eq. 15)

65

Where T.A. indicates application of MAC's Table of Allowances

Figure 14. Cochran Elevator Requirement Equation

The critical relationship between FMC loaders and 40K loaders was found to be the number of cargo pallets that could be transported by each. Though both loaders have tonnage capacities of 40,000 pounds, the FMC loader is capable of carrying only four 463L pallets as compared to the 40K loader's capacity for five pallets (33:23,41). The fact that the weight of palletized cargo will rarely exceed the tonnage limits of either loader substantiates that the critical capability difference between the two loaders is the difference in number of pallets they can transport (22).

The FMC loader requirement was then determined using the same basic equation used to determine the 40K loader requirement. This equation was modified by only a 5/4 factor to reflect the lesser cargo transport capability of the FMC loader and hence, the greater loader requirement. This equation which was used to determine the requirement of FMC loaders for the single loader system for the year  $t_c$  is shown in Figure 15.

Phase II of this research has described how Research Question 2 was answered. That is, Phase II determined the manner in which the total substitution of WBA for NBA in U.S. flag carriers' medium- and long-range aircraft, along with changes in cargo activity, will alter MAC's future loader requirements. A description of the analysis which compared the costs associated with

$$\begin{aligned}
 &\text{Number of FMC Loaders Required for Year } t_c \\
 &= \left[ \begin{array}{c} \text{Number of 40K Loaders} \\ \text{In 1979 Inventory} \end{array} \right] \times \frac{5}{4} + \\
 &+ \left[ \frac{5}{4} \right] \times 20 \times \left[ \begin{array}{c} \text{T.A.} \left( \frac{\text{Aggregate Monthly Cargo Tonnage for Year } t_c}{20} \right) - \text{T.A.} \left( \frac{\text{Aggregate Monthly Cargo Tonnage for Year 1979}}{20} \right) \end{array} \right] \quad (\text{Eq. 16})
 \end{aligned}$$

Where T.A. indicates application of MAC's Table of Allowances

Figure 15. FMC Loader Requirement Equation

maintaining the dual loader system and implementing a single loader system by the year  $t_c$  may now begin.

### Phase III

Phase III addressed the research hypothesis. The dual loader system was compared to the single loader system in terms of cost. Loader requirements for the two systems were developed in Phase II. In Phase III, the economic analysis technique first required that loader acquisition profiles showing the number of loaders to be acquired and their year of acquisition be developed for the single and dual loader systems. These profiles allowed the economic analysis to account for the effect of the time value of money on the two loader systems' acquisition, operation, and maintenance costs. Second, the variables of acquisition cost, operation cost, and maintenance cost were considered. Third and finally, a net present value analysis was performed utilizing the two systems' loader requirements, loader acquisition profiles, and cost variables. The analysis compared the costs attributed to the continued use of the dual loader system to the costs attributed to the implementation of the single loader system for the period of years from 1981 up to and including year  $t_c$ . The time span of the analysis was  $t_s$  years, where  $t_s$  equalled  $t_c$  minus 1980.

### Loader Acquisition Profiles

Cargo loader acquisitions for the two loader systems were of two types; new loader acquisition and replacement acquisition. New loader acquisitions were those loader purchases that would insure that year  $t_c$  loader requirements would be satisfied. These acquisitions were based on an annual loader purchase rate to be applied over the  $t_s$  year period of the analysis. Replacement acquisitions were those loader purchases required to allow for replacement of loaders in inventory which had exceeded their service life.

New Requirement Acquisitions. The purchase rates of 40K loaders and Cochran elevators for the dual loader system were determined by first obtaining the number of MHE which represented the short fall between the 1979 inventories and the year  $t_c$  requirements. These figures were then divided by  $t_s$  to obtain constant annual purchase rates of 40K loaders and Cochran elevators for the analysis period of 1981 to year  $t_c$ . Information about 40K loader and Cochran elevator inventories for year 1979 were received from MAC/TRPP. Loader requirements for year  $t_c$  were developed in the "Aggregate Loader Requirements" section of Phase II. The purchase rate of FMC loaders for the single loader system reflected the purchases of loaders required to accommodate the projected increases in

annual cargo tonnage to year  $t_c$ . This requirement was obtained from the second term of Equation 16. This requirement divided by  $t_s$  was the constant annual purchase rate of FMC loaders of the single loader system for the analysis period of 1981 to year  $t_c$ . Constant annual purchase rates of loaders were considered appropriate for the analysis in as much as the yearly cargo tonnage increases described in Phase II were also assumed to be constant. In other words, a constant yearly increase in loader inventories will accommodate a constant yearly increase in cargo traffic. End-of-year purchases of cargo loaders were assumed with the purchases beginning in year 1981 for both the single and dual loader systems.

Replacement Acquisitions. The determination of the number and year of loader purchases for replacement of old loaders was based on acquisition dates of loaders in MAC's 1979 inventory (assuming beginning-of-year purchases) and assumed service lives of loaders. Again, end-of-year purchases were assumed.

For the dual loader system, ages of the 40K loaders and Cochran elevators in the 1979 inventory were obtained from MAC/TRPF (Transportation Facilities and Equipment Division at MAC Headquarters, Scott AFB). Although the stated service life of the 40K loader is eight years, the ages of the 1979 inventory of 40K loaders

indicated that a ten year or twelve year service life would be a more realistic assumption for this analysis. Rather than arbitrarily choose any one of these service lives as a base for determining the year of replacement purchases, individual loader replacement profiles were developed considering each of the service lives of eight years, ten years, and twelve years. Each of these profiles were treated independently in the economic analysis. The service life of the Cochran elevator was assumed to be ten years, as reported by MAC's Table of Allowances (Tech Order 36A-1-1301).

Replacement profiles for the single loader system involved the replacement of 40K loaders whose service lives had been reached with an equivalent number of FMC loaders. The number of FMC loaders necessary to eventually replace all of the 40K loaders was determined by multiplying the number of 40K loaders in inventory by the  $5/4$  factor described in the previous section of determining aggregate loader requirements for the single loader system. The number of FMC loaders required to replace annual numbers of 40K loaders whose service lives had been reached was determined by applying this same  $5/4$  factor. It was assumed that the first year acquisition of FMC loaders would completely eliminate the requirement for Cochran elevators for the following year (e.g., the number of FMC loaders initially acquired would completely satisfy

the future "cargo demand" associated with the Cochran elevators). Two replacement profiles were prepared for the single loader system. One profile used a ten year service life for both the 40K loaders in inventory and the FMC loaders which will replace them. The other replacement profile applied a twelve year service life to both the 40K and FMC loaders. The service lives for the two loaders were considered the same in each replacement profile because it was assumed that MAC would maintain a constant service life policy as long as the manufacturer's service life estimates for the two loaders were at least similar. The manufacturer's recommended service life for the FMC loader was ten years (41). Of course, the two replacement profiles for the single loader system were treated individually in the economic analysis.

The new loader purchase rates of the two cargo loader systems were combined with the determined loader replacement profiles of the two loader systems to obtain overall loader acquisition profiles. The dual loader system acquisition profiles reflect total purchase requirements for the 40K loader and the Cochran elevator for the period of years 1981 to  $t_c$ . Three profiles were developed based on eight, ten, and twelve year service lives for the 40K loader while the elevator service life was assumed to be ten years. The single loader system acquisition profiles reflected total purchase requirements

for the FMC loader for the period of years 1981 to  $t_c$ . Two profiles were developed based on ten and twelve year service lives for both the FMC loader and the 40K loader that it would replace. As previously inferred, each of these five acquisition profiles were considered individually in the present value analysis.

### Cost Variables

Description of the Populations. The three variables or populations that were used in the present value analysis of this phase were the acquisition costs of cargo loader, the labor costs for loader operation, and the labor costs for loader maintenance. Two other cost variables that were to be developed for the analysis were loader operation costs associated with fuel consumption and loader maintenance costs associated with spare parts, oil, etc. However, these two cost variables were unable to be developed for all the cargo loaders of the single and dual loader systems. Hence, it was necessary to assume that operation and maintenance costs other than those associated with labor requirements were equal between the dual loader and single loader systems so that consideration of these costs could be dropped from the analysis. Specifically then, loader acquisition costs and operation and maintenance labor costs were the dependent variables of the analysis and time was the

independent variable. The unit of observation of the dependent variables was dollars. The unit of observation of time was years. The corresponding universe of the acquisition cost variable was the physical set of cargo loaders. The set of cargo loaders consisted of the 40K loader, the Cochran elevator, and the FMC loader. The universes of the two labor cost variables were the physical set of personnel required for loader operation in MAC and the physical set of loader maintenance personnel in MAC. These physical sets may be broken into groups of operating personnel and maintenance personnel for the 40K loader, the Cochran elevator, and the FMC loader.

Data Collection. Acquisition costs of loaders were equated to loader purchase price plus a loader delivery transportation fee estimated at 3 percent of the purchase price (15). The purchase price of the 40K loader was obtained from MAC/TRPF. The purchase prices of the Cochran elevator and FMC loader were obtained from the Warner-Robbins Air Logistics Center (15).

Operation costs for the single loader and dual loader systems were determined as a function of the number of personnel required for loader operation, the total number of hours of annual operation of the loader system, and the average hourly wage of the personnel involved with loader operation. For purposes of simplification of the

operation cost determination, it was assumed that the total number of hours of annual operation for the single loader system was equal to that for the dual loader system. Also, because both loader systems were to be manned by MAC personnel, the average hourly wage for personnel involved with loader operation was the same for the single loader and dual loader systems. Thus, the only difference in operation costs of the single and dual loader systems was due to possible differences in numbers of personnel required for loader system operation. The number of personnel required to operate the dual loader system was acquired from MAC/TRPP. This personnel requirement consisted of 40K loader operators and personnel who performed the functions of aligning the loader with the aircraft and moving cargo pallets from loader/elevator into the aircraft (20). The number of personnel required to operate the single loader system was determined from the number of FMC loader operators required and a similar number of personnel required for aligning loader to aircraft and moving pallets as in the dual loader system. The number of operators required for the FMC loader was obtained from American Airlines' Ground Equipment Engineering Group at Tulsa, OK (2). Total annual hours of operation for the two loader systems were obtained by multiplying number of hours of operation per vehicle for 40K loaders by the number of 40K loaders in

inventory. The average number of hours of operation for a 40K loader was assumed to be constant over time and was determined as the average of MAC's 1978 and 1979 Vehicle Management Report figures showing number of operation hours per vehicle for 40K loaders (see Appendix K). The total annual hours of operation of the Cochran elevator was determined as a percentage of the total annual hours of loader system operation. This percentage was assumed to be equal to the percentage of MAC's total annual cargo tonnage that was transported by WBA. Tonnage information was acquired from the derived forecast of MAC cargo activity (see Appendix H). The 40K loader inventory levels were obtained from the loader requirements analysis of Phase II and the loader acquisition profiles described in the first section of Phase III. An average hourly wage was based on an average of the wages paid to military and civilian personnel who were involved in the loading operation. MAC/TRPP supplied the ranks and wage grades of the military and civilian personnel who would perform in the loader operation role (45).

Maintenance costs for the single and dual loader systems were determined as a function of loader inventory, the historical average maintenance man-hours per loader, and the hourly wage of maintenance personnel. It was assumed that average maintenance man-hour (MMH) per

vehicle figures would remain constant over time. The annual maintenance cost equation was:

$$\begin{array}{rcl} \text{Maintenance} & & \\ \text{Cost} & = & \text{Number of Loaders in Inventory} \times \text{Average MMH per Loader} \\ & & \times \text{Average Wage of Maintenance Personnel} \end{array}$$

(Eq. 17)

Loader inventories were obtained from the loader requirements determination of Phase II and the loader acquisition profiles described previously in Phase III. MMH information for the 40K loader was obtained from the 1978 and 1979 Vehicle Management Reports (see Appendix K). MMH information for the Cochran elevator was provided by Pan American Airlines (13). The Ground Equipment Engineering Group of American Airlines at Tulsa, OK, provided MMH information for the FMC loader (2). The hourly wage of maintenance personnel was assumed to be the same wage received by personnel involved in loader operation.

#### Present Value Analysis

Present value analysis is a discounted cash flow approach to evaluating proposals (44:74). With regard to this research, two general proposals that were evaluated were the continued use of MAC's dual cargo

loader system and the implementation of a single cargo loader system. More specifically, five proposals were evaluated. The three loader acquisition profiles of the dual loader system required three separate proposal evaluations. The two loader acquisition profiles of the single loader system required an additional two proposal evaluations. The approach to this analysis was to associate the specific costs of each proposal with the year in which they would accrue and then to determine the net present value of each proposal via consideration of the time value of money. The period of years for which costs were considered began with the earliest year in which costs might accrue in the implementation of a single loader system; e.g., the year 1981. The last year of the study was the estimated year in which WBA would replace NBA in U.S. flag carriers' medium- and long-range aircraft, e.g., year  $t_c$ . The number of years this study considered was  $t_s$ , where  $t_s$  equalled  $t_c - 1980$ .

Acquisition Outlays. Loader acquisition outlays of each proposal were determined by applying the acquisition cost(s) of the appropriate loader(s) to each proposal's loader profile. Loader acquisition profiles and loader acquisition costs were developed in the previous sections of Phase III.

Annual Operation Costs. As stated in the "Cost Variables" section of Phase III, the only factor differentiating operation cost between the single and dual loader system was the number of personnel required for loader system operation. This single difference was based on the assumptions that the total hours of operation of the two systems were equal and hourly wages of the operation personnel of the two systems were equal. This situation allowed the researchers to simplify the determination of operation costs for the two cargo loader systems. Based on the economic analysis technique of accounting for only cost "differences" between proposals, operation costs were tracked only for the outstanding number of operation personnel required of the single or dual loader system. For any given workload, the "Cost Variables" section of Phase III assumed that the numbers of operation personnel required by the single loader and dual loader systems for aligning loaders to the aircraft/elevator and moving cargo pallets were equal. Hence, these labor costs were eliminated from the analysis. The remaining labor costs were associated with the operator requirements of the 40K loader, Cochran elevator, and FMC loader. The outstanding number of loader operators one system required over the other was then determined by comparing the loader operator requirements of the 40K loader and Cochran elevator with the loader requirements of the FMC loader. Once this

outstanding labor requirement of one of the loader systems was obtained, the annual labor cost of this requirement was calculated and accrued to that loader system having the outstanding labor requirement. This cost determination consisted of the product of the outstanding loader operator requirement, the total annual hours of loader operation, and the average hourly wage of the operation personnel. Each of these cost factors was described in the "Cost Variables" section of Phase III.

Annual Maintenance Costs. Annual maintenance costs for the dual loader system proposals were a sum of the annual maintenance costs of the 40K loader and Cochran elevator. Both the 40K loader's and Cochran elevator's annual maintenance costs were obtained from multiplication of loader inventory, average MMH, and the average hourly wage of maintenance personnel. Annual maintenance costs for the two single loader system proposals were a sum of the maintenance costs accrued to the FMC loader and the remaining inventory of 40K loaders and Cochran elevators. Both loader's annual maintenance costs were a product of their loader inventory, average MMH, and the average hourly wage of maintenance personnel. These three factors of loader inventory, MMH, and maintenance wages were addressed in the "Cost Variables" section of Phase III.

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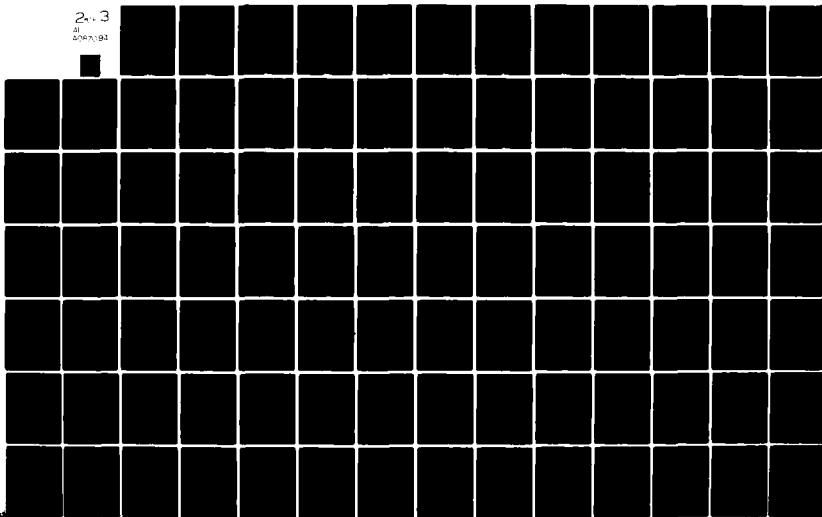
AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/6 15/5  
AN ANALYSIS OF THE FUTURE REQUIREMENTS FOR MATERIALS HANDLING E--ETC(U)  
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Consideration of Inflation Rates. Inflation had no effect on the outcome of the net present worth analysis of loader system proposals if each cost variable considered inflated at the same rate (16). If this were not the case, it was necessary to apply appropriate inflation factors to the categories of costs having different inflation rates prior to totaling and discounting of the total annual costs. The researchers suspected that the inflation rate for loader acquisition costs might be greater than that for the hourly wages of civilian and military personnel involved in the operation and maintenance of the proposed loader systems. Therefore, average inflation rates for acquisition costs and labor compensation were determined and compared. The USAF Cost and Planning Factors document provided raw inflation indexes and inflation factors for total military compensation, civilian personnel pay, and procurement costs for the years of 1980 through 1986 (42:111-113). Average annual inflation rates were then determined for each of these three types of costs. Next, an aggregate military/civilian annual compensation inflation rate was obtained as an average of the determined military compensation and civilian pay inflation rates. Final judgement as to the need for utilizing inflation factors in the present value analysis of cargo loader proposals was based on the comparison of the aggregate military/civilian annual inflation estimate to the

procurement annual inflation estimate. If these inflation estimates were similar, it was assumed that inflation would not affect the present value analysis of loader system proposals. If these wage and procurement inflation rate estimates were dissimilar, it was necessary that inflation factors corresponding to these inflation rates be applied to each proposal's annual labor and acquisition costs prior to the totaling and discounting of annual costs.

Present Value Determination. For each of the five loader system proposals, total costs were calculated by summing acquisition costs, operating labor costs, and maintenance labor costs for each year in which they were to be accrued. Pending the consideration of inflation rates, acquisition costs and labor costs were either base line figures or inflated figures. Following this, government recommended 10 percent present value factors were applied to these cost totals to obtain the annual discounted costs of the five loader system proposals (28:174; 38:368). Finally, the annual discounted costs of each proposal were summed to arrive at a net present value for each loader system proposal.

Criteria Test. Proposals of the single loader system were compared to those proposals of the dual loader system having similar loader service life assumptions.

That is, single and dual system proposals which had similar assumptions concerning the length of service life for the 40K and FMC loader were compared. For each comparison of single system proposal to dual system proposal, the proposal having the lower net present value was the more cost effective.

### Assumptions

#### Phase I

1. Rev-Tons carried by WBA is a direct substitute for Rev-Tons carried by NBA.
2. U.S. civilian wide-bodies will eventually replace U.S. civilian narrow-bodies.
3. The forecast of the substitution of WBA for NBA was an accurate representation of the future. In other words, future causal conditions that would drastically affect the aircraft industry such as technological advances will not occur.

#### Phase II

1. The aggregate forecast of cargo tonnages was an accurate representation of the future (see Phase I, Assumption 3).
2. The MAC 7107 Report provided an accurate picture of monthly cargo activity in spite of the fact that many additions and deletions occur in MAC mission schedules over time.

3. Factors affecting cargo loader requirements other than cargo tonnage workloads remained constant through the period of years 1980 to  $t_c$ .

4. A constant requirement for 25K loaders existed whether MAC maintained the dual loader system or implemented a single loader system.

5. The requirement for 25K loaders in MAC remained satisfied through the period of years 1980 to  $t_c$ .

6. MAC's Table of Allowances for K-loaders (Tech Order 36A-1-1301) was appropriate for determining Cochran elevator requirements based on cargo tonnage workloads.

7. The FMC cargo loader was representative of the type of loader MAC would choose to purchase for a single loader system.

8. The critical capability difference between the 40K loader and the FMC loader was the number of cargo pallets each could transport.

9. Loader requirement Equations 14, 15, and 16 accurately reflected future loader requirements for the dual loader and single loader systems.

### Phase III

1. Constant annual purchase rates of cargo loaders satisfied increased loader requirements due to annual increases in cargo transport tonnages.

2. End-of-year purchases of cargo loaders were contracted.

3. The service life of the Cochran elevator was ten years.

4. For the single loader system, 40K loaders were replaced with equivalent numbers of FMC loaders based on cargo pallet-transporting capabilities.

5. For the single loader system, the first year acquisition of FMC loaders completely eliminated the requirement for Cochran elevators the following year.

6. MAC will maintain a constant service life policy with respect to cargo loaders.

7. Operation and maintenance costs other than those associated with labor were equal between the single and dual loader systems.

8. The total number of hours of annual operation for the single loader and dual loader systems were equal.

9. The average pay wage for loader operation personnel of the single loader and dual loader systems were equal.

10. Similar numbers of operation personnel were required for the single loader and dual loader systems for purposes of aligning loaders to the aircraft and moving cargo pallets.

11. MAC's Vehicle Management Reports of 1978 and 1979 present accurate figures of average operation hours and average MMHs for the 40K loader.

12. The average hours of operation of the 40K loader remained constant over time.

13. MMH information obtained for the Cochran elevator from Pan American Airlines was reliable.

14. MMH information obtained for the FMC loader from American Airlines was reliable.

15. The average MMHs for the 40K loader, Cochran elevator, and FMC loader remained constant over time.

16. The percentage of MAC's total annual cargo tonnage that was transported by WBA accurately reflected the percentage of the total annual hours of operation of the dual loader system in which the Cochran elevator was in operation.

17. The average hourly wage of maintenance personnel was equal to the average hourly wage of operation personnel.

### Limitations

#### Phase I

1. The data obtained from the CAB report was only available for the years 1970 through 1975.

2. Supplemental air carriers were not included in the substitution rate forecast.

3. The evaluation of the substitution rate forecast possessed only 80 percent confidence.

#### Phase II

1. Data concerning MAC cargo activity were obtained only for the twenty major aerial ports.

2. The data obtained from the MAC 7107 Report were available only for the past six years.

3. The evaluation of the linear trend forecast possessed only 80 percent confidence.

4. The regression model may not be appropriate under future causal conditions different from those in the present.

5. The determination of MAC's future loader requirements on an aggregate level extremely simplified the MHE aspect of this analysis. Therefore, as a result of not having considered the MHE demands of individual bases, the study ignored possible future problems such as conflicts in the scheduling of Category B missions, base-level loader shortages, and cargo activity disruptions due to equipment rotation or replacement.

#### Phase III

1. The Vehicle Management Reports of 1978 and 1979 reflected data for numbers of 40K loaders that were less than the actual 40K inventories. Therefore, the

average hours of operation and average maintenance man-hour figures of the 40K loader were based on an incomplete inventory of loaders for years 1978 and 1979.

2. The single loader system was evaluated in terms of costs associated with only one of several brand name cargo loaders which could have filled the single loader system role.

3. Inflation planning data reflected estimates of future economic trends as determined by the federal government. One would have to question the validity of such predictions of trends as variable as those of the economy.

4. The validity of the researchers' conclusions was questionable if operation and maintenance costs other than those associated with labor were significantly different for the single loader and dual loader systems.

5. The validity of the researchers' conclusions was questionable if MAC did not plan to acquire loaders at a constant purchase rate.

6. The validity of the net present value analysis was questionable if the discount rate of 10 percent was found inappropriate.

## CHAPTER III

### ANALYSIS AND INTERPRETATION OF RESULTS

#### Phase I

After the methodology to be used in this research study had been proposed, the outlined procedures were followed and results were secured. These results are presented and discussed in this chapter. The presentation and discussion of the results should provide guidance in relation to MAC's MHE decision.

#### Data Collection

In order to develop the substitution rate forecast, data were first obtained from the CAB's Aircraft Operating Cost and Performance Report for the years 1970 through 1975. Equations 1, 2, and 3 were then utilized to acquire revenue tonnage information for specific WBA and NBA in inventory. Finally, total WBA Rev-Tons and total NBA Rev-Tons for each year were calculated by summing the appropriate aircraft data. These final results of the data collection are found in Appendix B. By analyzing these statistics, the reader can definitely see that during the early to mid-70s there seemed to indeed be a substitution of WBA for NBA. Therefore, the model used in Phase I was most likely very applicable to this research.

### Substitution Rate Forecast

The forecast for this aircraft situation consisted of three primary steps. First, the appropriate data were grouped, the IAETRs were computed, and an average  $z$  was determined. In this situation  $z$  equalled 0.232 (see Appendix C). Second,  $t_0$  was calculated using Equation 4. For  $z$  equal to 0.232 and  $t$  equal to 1975:

$$f = 1/2[1 + \text{TANH } z(t-t_0)]$$

$$0.5668 = 1/2[1 + \text{TANH } 0.232 (1975 - t_0)]$$

$$1.1336 = 1 + \text{TANH } 0.232 (1975 - t_0)$$

$$0.1336 = \text{TANH } 0.232 (1975 - t_0)$$

$$0.1344 = 0.232 (1975 - t_0)$$

$$0.5793 = 1975 - t_0$$

so,

$$t_0 = 1975 - 0.5793$$

$$= 1974.4207$$

$$\approx 1974.4$$

Therefore, with respect to U.S. civilian WBA replacing NBA, 50 percent take-over should have taken place in approximately the middle of 1974. The reader should recognize from the existing data that WBA have a fairly

good "head start" in this forecast (i.e., 57 percent take-over in 1975). Finally, the revenue tonnage forecast was made. This trend for Rev-Tons was calculated by solving Equation 4 for  $f$  with  $z$  equal to 0.232,  $t_0$  equal to 1974.4 and  $t$  equal to some specified year in the future. One can see in Appendix C that with the criterion of 99.95 percent substitution, Rev-Tons moved by WBA is predicted to take-over NBA movement about the year 1991. A plot of this forecast appears in Figure 16. In effect, Research Question 1 was answered by the analysis.

#### Evaluation of the Substitution Rate Forecast

So as to assess the accuracy of the NBA replacement forecast, a prediction interval formulation was accomplished. Data used for developing the 80 percent prediction interval can be found in Appendix D. Statistics produced by MLREG and utilized in the computations are shown also in this appendix. Given the following:

$$w_{t_c} = -3.290$$

$$t_c = 21 \text{ (the coded year for 1991 since 1970 equalled zero)}$$

$$t(1-\alpha/2; n-2) = t(0.9; 4) = 1.533$$

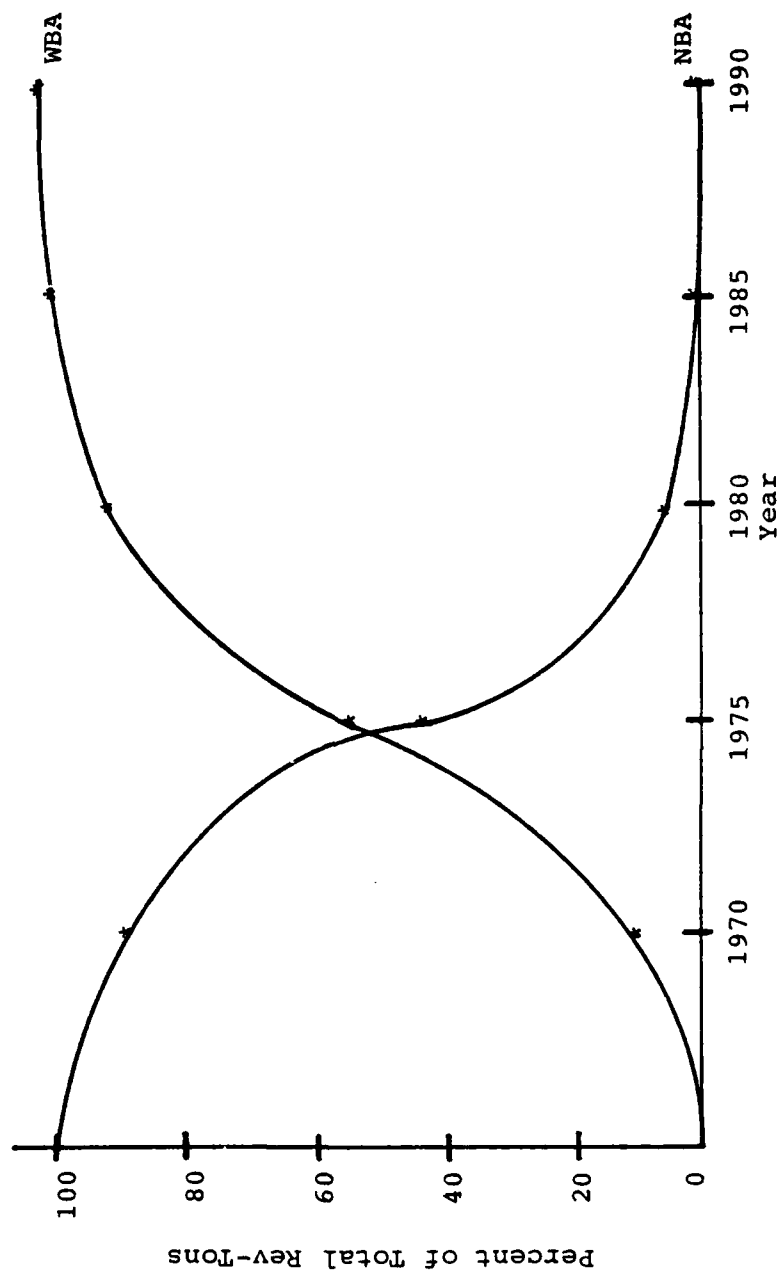


Fig. 16. Substitution of WBA for NBA

$$\alpha = 0.2$$

$$n = 6$$

$$s(d_{t_c}) = 0.552$$

the interval was determined with the use of Equation 7:

$$\begin{aligned} w_{t_c} - t(1-\alpha/2; n-2) s(d_{t_c}) &\leq w'_{t_c} \leq \\ &w_{t_c} + t(1-\alpha/2; n-2) s(d_{t_c}) \\ -3.290 - 1.533 (0.552) &\leq w'_{t_c} \leq -3.290 + 1.533 (0.552) \\ -3.290 - 0.846 &\leq w'_{t_c} \leq -3.290 + 0.846 \\ -4.136 &\leq w'_{t_c} \leq -2.444 \end{aligned}$$

NOTE:  $w'_{t_c} = \text{LOG } y/(1-y)$

$$\begin{aligned} -4.136 &\leq \text{LOG } y/(1-y) \leq -2.444 \\ 0.00007 &\leq y(1-y) \leq 0.00360 \\ 0.00007 &\leq 1/(1-y) - 1 \leq 0.00360 \\ 1.000 &\leq 1/(1-y) \leq 1.004 \\ 1.000 &\geq (1-y) \geq 0.996 \\ 0 &\geq -y \geq -0.004 \\ 0 &\leq y \leq 0.004 \end{aligned}$$

Specifically, one can be 80 percent confident that the fraction of NBA Rev-Tons remaining to be taken-over in

1991 is between 0 and 0.4 percent. As indicated by the small prediction interval, this substitution forecast should be fairly accurate. When considering the forecast projection of 0.05 percent, however, the interval is really somewhat wide. Still, since the largest fraction of NBA Rev-Tons remaining is only 0.4 percent (largest side of the interval), it can be concluded that a total replacement of NBA by WBA was insured by this forecast.

In summary, the prediction interval for the substitution rate forecast is of significant value in answering Research Question 1. That is, when will U.S. civilian WBA actually replace U.S. NBA? The technological forecast provides conservative results indicated by the width and magnitude of the prediction interval associated with a moderate confidence level. Yet, the reader should realize that at an 80 percent level of confidence, no more than 0.4 percent of all Rev-Tons is forecast to be flown by NBA in the year 1991. Therefore, in light of the assumptions made in utilizing the substitution rate forecast, the prediction for  $t_c$  (e.g., 1991) should serve as a useful basis for Phase II.

## Phase II

### Aggregate Forecast of MAC Cargo Activity

Data Collection. In order to develop an aggregate forecast of MAC cargo activity, monthly data were first

collected from MAC 7107 Reports covering the years 1974 through 1979 and tabulated according to movement (i.e., tonnage flown by civilian Non-ASIF aircraft). Again, cargo information was only gathered for MAC's twenty major aerial ports. A summary of the tonnage tabulations is presented in Appendix E (Summary A) (in this summary one should note that tonnage flown by military ASIF and Non-ASIF aircraft were combined). Lastly, the data were regrouped (e.g., by total tonnage, military and civilian Non-ASIF tonnage, and civilian ASIF tonnage) and the average monthly tonnage for each year by grouping was calculated. These computations provided data in the form needed to build a forecast which would be consistent with Phase I and the second part of this phase. The average monthly tonnages for the years 1974 through 1979 are also found in Appendix E (Summary B).

Linear Trend Forecast. Before using the linear trend model for the cargo activity forecast, the historical data pertaining to the average monthly total tonnage and the average monthly WBA tonnage were plotted for the past six years. These plots are presented in Figures 17 and 18. Unfortunately, the plots of the existing data did not distinctly exhibit a linear trend. In fact, as one can see, they really did not reflect any mathematical relationship that would be realistic to use in this

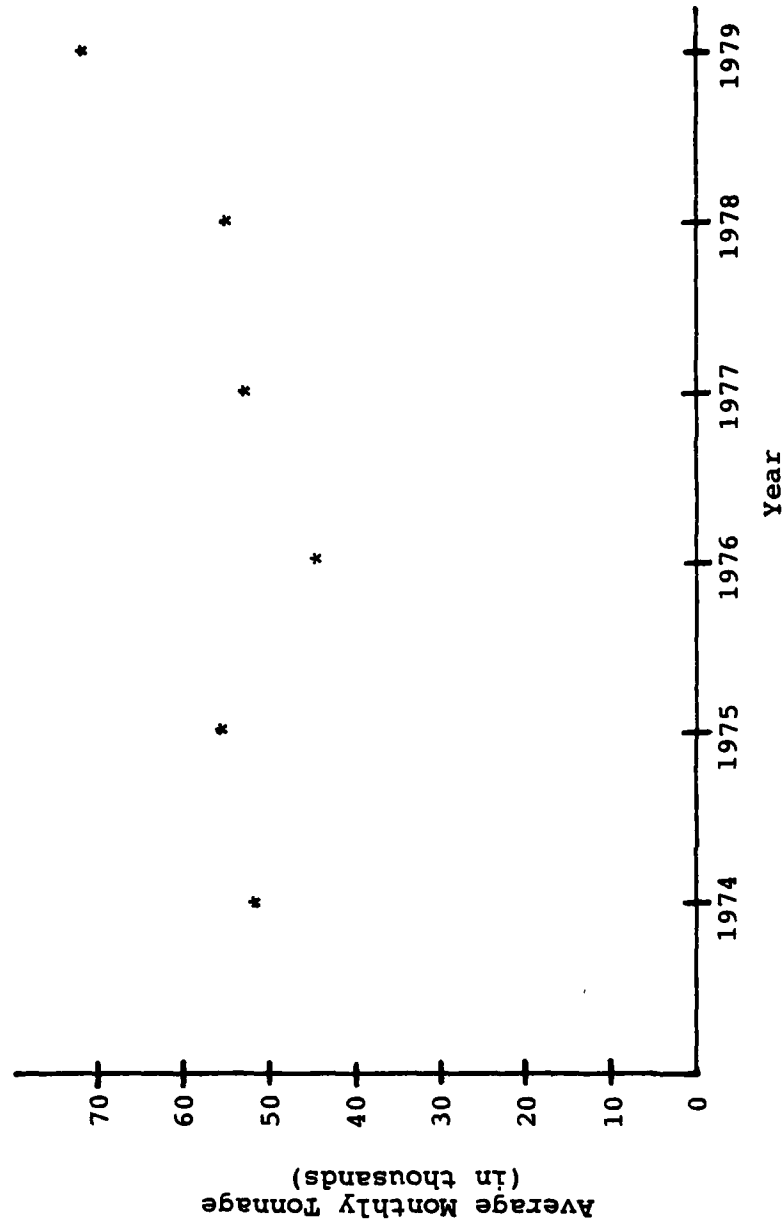


Fig. 17. MAC Cargo Activity--Total Tonnage

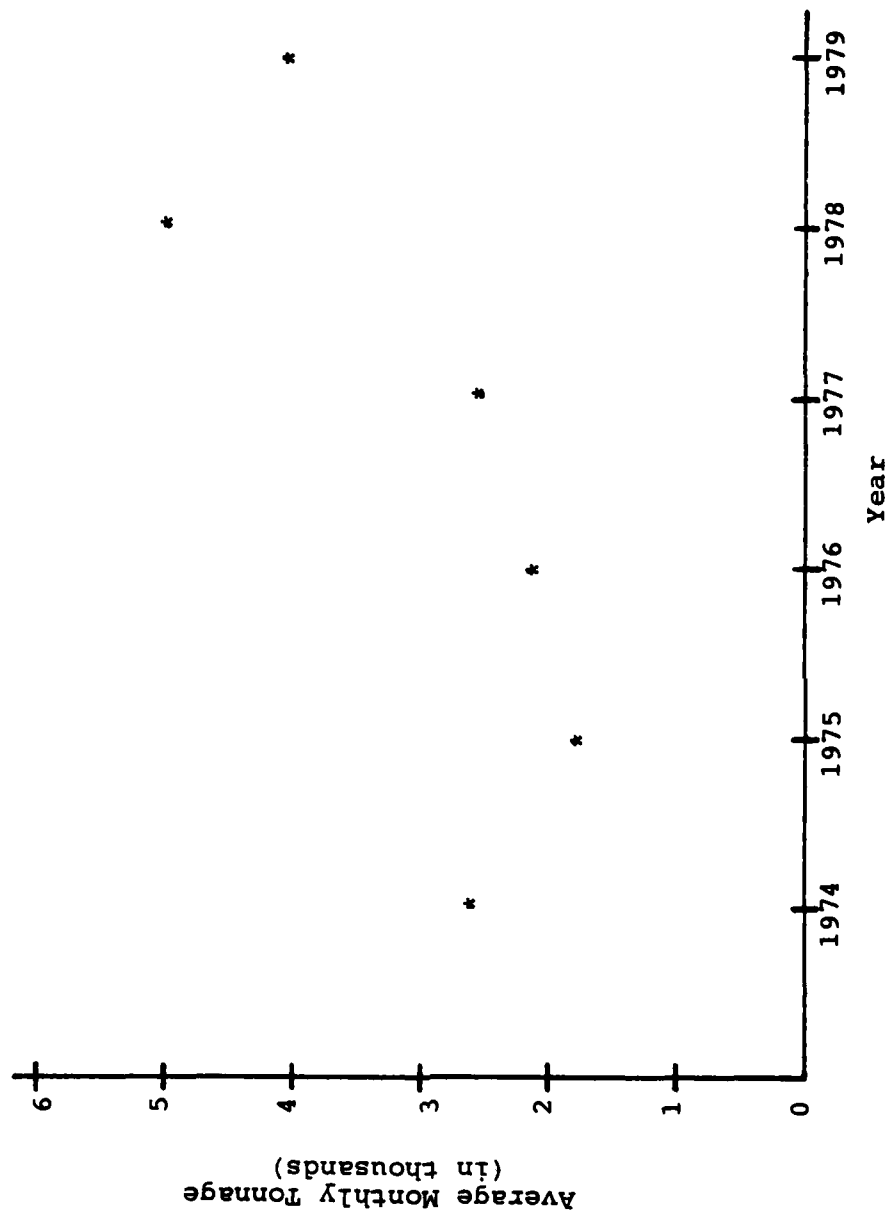


Fig. 18. MAC Cargo Activity--Civilian ASIF (WBA) Tonnage

situation. After visually analyzing the two plots, an initial conclusion was drawn that it would be very dangerous to apply some type of model which might provide extremely unreasonable predictions at some point in time (i.e., a quadratic function will "explode" outside of a specific domain). In addition, when considering the uncertainty of the future, justification for employment of such a model would be almost impossible. In relation to the plots, another possibility was to eliminate some of the data points from the study. For instance, if the 1974 and 1975 values for average total tonnage flown monthly were dropped, the remaining points show a fairly clear-cut linear trend. However, this research team felt that it would be very difficult to justify such an elimination, especially when so few data points were being used in the first place. Thus, the decision was made to utilize the linear trend model. This decision was based on two major reasons: (1) the model would provide a "conservative" forecast in this case (e.g., considering the historical tonnage data) and (2) the model is easy to apply in the average work environment.

By manipulating the existing data through the use of MLREG, the estimated linear regression lines for total tonnage and WBA tonnage were derived (See Appendix F). As the reader can see from the output, the simple coefficients of determination ( $r^2$ ) for the two lines were low

(0.30 and 0.55 for total tonnage and WBA tonnage, respectively). The coefficient of determination,  $r^2$ , is a measure of the proportion of variation which is explained (reduced) by the regression line (29:457-458). In other words, this coefficient indicates how useful the proposed relation really is. One can then understand that the linear trend model was not too helpful in this case. Yet, as previously explained, the model was still used in spite of the low  $r^2$ s since there was a lack of other relationships which could provide a more realistic forecast.

Corresponding to the total tonnage and WBA tonnage lines, the following regression functions were determined by MLREG<sup>8</sup>:

For average total tonnage flown monthly:

$$T_t = a + bX_t = 44280.950 + 1552.571 X_t$$

For average tonnage flown monthly by WBA:

$$T_t = c + dX_t = -133.229 + 495.343 X_t$$

---

<sup>8</sup>The regression equations computed by MLREG were multiplied by ten in order to obtain the correct tonnage functions. This manipulation was necessary because the input data had been originally divided by ten so that the regression results would "fit" in the "canned" program's output formats.

By looking at the b and d coefficients, or slopes, of the two lines, the reader can see that aggregate cargo activity for these groupings is predicted to increase in the future. (In addition, average tonnage flown monthly by military aircraft and narrow-bodies would rise due to its relationship to these two groupings.) So, in order to determine the projected increase in average monthly total tonnage and average monthly WBA tonnage, one had to solve the two equations for the appropriate  $X_t$ . In this phase of the research it was desired to predict the cargo activity in the year in which U.S. civilian WBA would completely replace NBA ( $t_c$ ). Using the results of Phase I and plugging  $X_t = 21$  (the coded year for 1991 since 1970 equalled 0) into both formulas, the following forecasts resulted:

For average total tonnage flown monthly in 1991:

$$T_t \approx 76,885 \text{ tons per month}$$

For average tonnage flown monthly by WBA in 1991:

$$T_t \approx 10,269 \text{ tons per month}$$

As the reader can detect by comparing these figures to the 1979 data, the rise in monthly total tonnage from 1979 to 1991 is predicted to be only about 23 percent while the rise in monthly WBA tonnage is forecast to be approximately 147 percent. Now, the question is: How will these

tonnage predictions affect MAC's loader requirements for both alternatives of maintaining a dual MHE system and converting to a single system?

Evaluation of the Linear Trend Forecast. As stated in the methodology, a criteria test in this phase would normally consist of two parts. These two parts would include an evaluation of model aptness and a prediction interval formulation. However, in this situation where the use of some relationship other than the linear trend forecast could not really be justified, a test of model appropriateness simply was not necessary. The sole reason for using the linear trend model was to provide MAC with conservative tonnage projections. Therefore, the criteria test in this section only involved a prediction interval construction.

The data which were used for developing the two 80 percent prediction intervals consisted of the historical information pertaining to average monthly total tonnage and average monthly WBA tonnage (See Appendix E). Statistics produced by MLREG and utilized in the computations are presented in Appendix G.<sup>9</sup> Given the following:

---

<sup>9</sup>The reader should note that the statistics produced by MLREG were multiplied by ten before being used in the prediction interval calculations. This manipulation was necessary because the input data had been originally divided by ten so that the regression results would "fit" in the "canned" program's output formats.

For average total tonnage flown monthly in 1991:

$$T_{t_c} = 76,884.945$$

$$t_c = 21 \text{ (the coded year for 1991 since 1970 equalled 0)}$$

$$t(1-\alpha/2; n-2) = t(0.9; 4) = 1.533$$

$$\alpha = 0.2$$

$$n = 6$$

$$s(d_{t_c}) = 18,168.631$$

the interval was determined with the use of Equation 13:

$$T_{t_c} - t(1-\alpha/2; n-2)s(d_{t_c}) \leq T'_{t_c} \leq T_{t_c} + t(1-\alpha/2; n-2)s(d_{t_c})$$

$$76,884.945 - 1.533 (18,168.631) \leq T'_{t_c} \leq$$

$$76,884.945 + 1.533 (18,168.631)$$

$$76,884.945 - 27,852.511 \leq T'_{t_c} \leq$$

$$76,884.945 + 27,852.511$$

$$49,032.434 \leq T'_{t_c} \leq 104,737.456$$

or

$$49,032 \leq T'_{t_c} \leq 104,737$$

For average tonnage flown monthly by WBA in 1991:

$$T_{t_c} = 10,268.971$$

$$t_c = 21 \text{ (the coded year for 1991 since 1970 equalled 0)}$$

$$t(1-\alpha/2; n-2) = t(0.9; 4) = 1.533$$

$$\alpha = 0.2$$

$$n = 6$$

$$s(d_{t_c}) = 3,391.782$$

the interval was determined with the use of Equation 13:

$$T_{t_c} - t(1-\alpha/2; n-2)s(d_{t_c}) \leq T'_{t_c} \leq T_{t_c} + t(1-\alpha/2; n-2)s(d_{t_c})$$

$$10,268.971 - 1.533 (3,391.782) \leq T'_{t_c} \leq$$

$$10,268.971 + 1.533 (3,391.782)$$

$$10,268.971 - 5,199.602 \leq T'_{t_c} \leq$$

$$10,268.971 + 5,199.602$$

$$5,069.369 \leq T'_{t_c} \leq 15,468.573$$

or

$$5,069 \leq T'_{t_c} \leq 15,469$$

Specifically, one can be 80 percent confident that the total tonnage flown monthly in 1991 is between 49,032 and 104,737 tons while the tonnage flown monthly by WBA in 1991 is between 5,069 and 15,469 tons. As indicated by the wide prediction intervals (e.g., the interval widths are 72 percent and 101 percent of the  $T_{t_c}$  point estimate for average monthly total tonnage and average monthly WBA tonnage, respectively), the linear trend forecast did provide some "rough" projections. Still, the reader must realize that as a result of future uncertainty, an attempt was only made to provide MAC with moderate tonnage predictions. The linear trend model used in this phase did just that. The forecast evaluation proved that the tonnage estimates predicted for 1991 are no more than conservative ones. Thus, in spite of the fact that they are simply "rough" estimates, the cargo activity projections are probably as good as any others and should serve as a useful basis for the rest of Phase II.

#### Aggregate Loader Requirements

The 40K loader requirement of the dual loader system for year 1991 was determined by using Equation 14. Values of equation variables are as follows:

Projected Aggregate Monthly Tonnage for 1991	76,885
Aggregate Monthly Tonnage for 1979	58,415
1979 Inventory of 40K Loaders	137

The calculated aggregate 40K loader requirement for year 1991 was 157. The Table of Allowances used for this determination is presented in Table 2.

The elevator requirement of the dual loader system for year 1991 was determined by using Equation 15. Values of equation variables are as follows:

Projected Aggregate Monthly Tonnage for 1991	10,269
Number of Air Bases Accommodating WBA	19

The calculated aggregate Cochran elevator requirement for year 1991 was 19. The Table of Allowances used for this determination is presented in Table 2.

The FMC loader requirement for the single loader system for year 1991 was determined by using Equation 16. Values of equation variables are as follows:

Projected Aggregate Monthly Tonnage for 1991	76,885
Aggregate Monthly Tonnage for 1979	58,415
1979 Inventory of 40K Loaders	137

The calculated aggregate FMC loader requirement for year 1991 was 197. The Table of Allowances used for this determination is presented in Table 2.

### Phase III

The period of this analysis was  $t_s$ , where  $t_s = t_c - 1980$ .  $t_c$  equalled 1991. Hence, the period of analysis was eleven years.

### Loader Acquisition Profiles

New Loader Acquisitions. The purchase rate of 40K loaders equalled:

$$\frac{1991 \text{ Loader Requirement} - 1979 \text{ Inventory}}{11}$$

$$\frac{157 - 137}{11} = 1.82$$

This purchase rate was adjusted to be a constant two-loader annual purchase rate which would be applied each year until the 1991 inventory requirement was met. The purchase rate of Cochran elevators equalled:

$$\frac{1991 \text{ Elevator Requirement} - \text{Number of Elevators in 1979 Inventory}}{11}$$

$$\frac{19 - 12}{11} = .64$$

This purchase rate was adjusted to be a constant one-elevator annual purchase rate which would be applied each year until the 1991 inventory requirement was met. The purchase rate of FMC loaders equalled:

$$\frac{\text{Value of Second Term of Eq.}}{11} = \frac{25}{11} = 2.27$$

This purchase rate was adjusted to be a constant five-loader biannual purchase rate for which consecutive yearly

purchases of two and three loaders were assumed. This purchase rate would be applied biannually until the 1991 inventory requirement was met.

Replacement Acquisitions. The dates of acquisition of the 40K loaders in the 1979 inventory are given in Appendix I. The dates of acquisition of the twelve Cochran elevators in the 1979 inventory were the year 1977. For the single loader acquisition profiles, the number of FMC loaders that eventually replaced the 1979 inventory of 40K loaders was:

$$\begin{aligned} \text{1979 Inventory of 40K Loaders} \times \frac{5}{4} &= 137 \times \frac{5}{4} \\ &= 171.25 \end{aligned}$$

This FMC loader replacement requirement for the single loader acquisition profiles was rounded up to 172.

Total loader acquisition profiles for the single loader and dual loader systems were developed and are shown in Appendix J.

#### Cost Variables

Acquisition costs for MHE equipment are shown in Table 3. The acquisition costs of the 40K loader and Cochran elevator together, were approximately equal to (actually less than) that of the FMC loader.

Table 3  
LOADER ACQUISITION COSTS

Loader Type	Price (\$)	3% Transportation Fee (\$)	Total Cost (\$)
40K	162,485	4,875	167,360
316A Elevator	116,279	3,491	119,870
Wide-body Mobile*	281,750	8,453	290,203

\*This loader was assumed to be FMC main deck loader (Model 238-4300)  
SOURCE: (15; 37)

Operation costs were tracked only for outstanding numbers of personnel between the single loader and dual loader systems. Research found that only one laborer was required to operate each 40K loader, Cochran elevator, or FMC loader. Thus, the dual loader system required one operator more than the single loader system. However, this outstanding labor requirement was not needed for the total hours of operation for the dual loader system. The outstanding labor requirement was associated with that percentage of time of total loader system operation in which the Cochran elevator was in operation. This percentage was estimated by the percentage of total annual MAC cargo tonnage that would be transported by WBA. The annual hours of operation for the Cochran elevator were determined by the following equation:

Hours of Elevator Operation

= Number of 40K Loaders in Inventory

x Average Operation Hours of 40K Loader

x  $\frac{\text{Tons Transported by WBA}}{\text{Total Tons Transported}}$  (Eq. 18)

Average annual operation hours for the 40K loader was 826 hours per vehicle. The determination of this figure from data provided in a summary of MAC's Vehicle Management

Reports is shown in Appendix K. Figures representing annual tons transported by WBA and total annual tons transported were obtained from the forecast of MAC cargo activity (see Appendix H). The cost associated with the outstanding labor requirement of the dual loader system was equated to the annual hours of operation for the Cochran elevator (Eq. 18) and the average wage received by personnel involved in loader operation. That is,

Outstanding Annual Cost of Operation of Dual Loader System

= Annual Hours of Elevator Operation

x Average Wage of Loader Operation Personnel

(Eq. 19)

The average wage for loader operation personnel was determined to be \$6.22 per hour. The calculations arriving at that wage are shown in Appendix L.

Annual maintenance costs of loaders were determined by using Equation 17. Average MMHs for the 40K loader was 571 hours per vehicle. The calculations arriving at this figure are shown in Appendix K. The average MMHs for the Cochran elevator was forty-two hours per elevator. The average MMHs for the FMC Loader was 923 hours per loader. The calculations which were needed in arriving at this figure are shown in Appendix M. Comparison of average MMHs for the single loader and dual

loader system indicated the MMHs of the FMC loader were substantially greater than the MMHs of the 40K loader or Cochran elevator. The average wage of maintenance personnel was \$6.22 per hour.

#### Present Value Analysis

Acquisition Outlays. Acquisition outlays for the 40K loader and Cochran elevator were determined for each of three dual loader system proposals and are given in Appendix N. The acquisition outlays for the FMC loader were determined for each of two single loader system proposals and are given in Appendix O.

Annual Operation Costs. Annual outstanding operation costs associated with the dual loader system were determined via Equation 19. Results are presented in Appendix P.

Annual Maintenance Costs. Annual maintenance costs were determined by using Equation 17. Annual maintenance costs of the 40K loader and Cochran elevator for the dual loader system are given in Appendix Q. Because loader and elevator inventories are the same across similar years of dual loader system proposals, the annual maintenance costs of the dual loader system are the same for each dual loader system proposal. Annual maintenance costs for each single loader system proposal's inventory

of the FMC loaders, 40K loaders, and Cochran elevators were determined and are presented in Appendix R.

Consideration of Inflation Rates. The aggregate military/civilian annual compensation inflation rate was determined to be 7.35 percent. The annual procurement inflation rate was determined to be 7.40 percent. It was concluded that these two inflation rates were approximately equal and that acquisition costs of loaders would inflate at the same rate as wages of the personnel involved in the operation and maintenance of loaders. As result of this conclusion, inflation factors were not applied to annual acquisition and labor costs in the net present value analysis. Calculations of the annual civilian personnel pay inflation rate, the annual military compensation inflation rate, and the annual procurement inflation rate are shown in Appendix S.

Present Value Determination. The 10 percent present value factors used in this analysis are presented in Appendix T. The present value calculations of each single loader and dual loader system proposal are also presented in Appendix T. Table 4 indicates the determined net present value of each loader system proposal. As the reader can see, the dual loader system in terms of present value is the better alternative.

Table 4  
NET PRESENT VALUE SUMMARY OF PROPOSALS

No.	Proposal	Service Life Assumption		Net Present Value (\$)
		MHE	Service Life (Years)	
1.	Dual Loader System	40K Loader	8	\$31,831,645
2.	Dual Loader System	40K Loader	10	24,882,892
3.	Dual Loader System	40K Loader	12	20,658,876
4.	Single Loader System	FMC Loader 40K Loader	10 10	47,726,666
5.	Single Loader System	FMC Loader 40K Loader	12 12	38,016,966

## CHAPTER IV

### CONCLUSIONS AND RECOMMENDATIONS

Through the use of the three-phase methodology proposed in this study to examine MAC's MHE problem, the researchers concluded that the USAF should continue to acquire, operate, and maintain the dual loader system. This conclusion was easily drawn after the results of the net present value analysis had been obtained. As indicated by the discounted cash flow totals, the dual system alternative should be selected for both the 10-year and 12-year life replacement policies. The "driving force" for this decision to keep on writing specifications around the K-loaders was actually threefold. First, the predicted change in MAC cargo activity on the aggregate level had a minimal effect on overall loader requirements. In essence, this minimal effect meant that a minimal number of elevator loaders had to be acquired for the dual system. One must realize that the small alteration in the number of required loaders was partially based on the forecasted substitution of U.S. civilian WBA for NBA. In other words, if the year in which WBA would replace NBA had been forecast differently, the final decision might possibly have been to convert to a single loader system

(i.e., if  $t_c$  had been the year 2000, the operations cost associated with the dual system would have been much larger). Second, the purchase price of the dual loader system (e.g., 40K loader and Cochran elevator) was lower than that of the single system (e.g., FMC loader). This lower initial investment provided the dual MHE system with yet another advantage. Finally, the MMH cost for the FMC equipment system was much more expensive when compared to the same cost for the K-loader/elevator system. This MMH aspect gave the dual system one more "edge" in the analysis. So, as the reader can see, these three factors were very influential in the solution to MAC's MHE problem.

In spite of the answer furnished by this research effort, a final vital point must be made. Even after it has been concluded that the dual loader system is the cost-effective alternative in this case, two factors should be considered. First, many assumptions were made which greatly simplified MAC's situation and the methodology of this study. With this in mind, the reader should question whether these assumptions will really reflect future reality. Second, a time series analysis as was performed in the first two phases of this study is a very tricky and complicated procedure. No one can exactly predict the future. In effect, the reader has to continually remember that future causal conditions may occur which

might drastically influence the assumptions made in the second chapter. Future events usually interact and thus affect the timing, expectancy, and impact with other events. For instance, with respect to the loader scenarios examined in this research, impacting events or trends may occur in the following areas:

1. The development and production of an aircraft which would not only fulfill the demands of MAC but which would also fit into the civilian cargo transport market (i.e., the C-XX cargo transport) (1:32).
2. The modification of the C-141 (e.g., the "stretch" C-141) (18).
3. Oil shortages which would affect the supply of aviation fuel.
4. A military conflict in which WBA would be utilized.
5. New and improved designs of commercial loaders capable of servicing both military aircraft and WBA.
6. Fluctuating trends in the U.S. and/or world economy.
7. Changes in the prices of 463L equipment and/or commercial cargo loaders.
8. Developments in the U.S. and/or foreign aircraft markets which might influence the demand for wide-bodies.
9. The closing of any major aerial port within MAC.

10. The contracting of all maintenance activity associated with 463L equipment (e.g., the elimination of "in-house" maintenance) (46).

Occurrences in these and other areas may necessitate a re-evaluation of the assumptions made and the forecasting techniques utilized in this research. An important point is that the future is never certain.

In conclusion, this study represented a research effort designed to analyze MAC's alternatives of maintaining its dual system of cargo loaders or converting to a single system compatible with both military aircraft and civilian WBA. Still, in light of the assumptions made and future uncertainties, further study in this MHE area is suggested. Specifically, the two authors make the following recommendations:

1. In relation to the events or trends which might possibly occur in the future, some type of cross-impact analysis should be performed. By considering the interacting forces of the future, this analysis would definitely improve the predictions provided by this study. In essence, the impact technique would expose internal inconsistencies of the forecasts and clarify underlying assumptions (5:11-1 to 11-2).

2. The substitution rate forecast of Phase I should be continually updated as current data on the actual replacement of NBA by WBA becomes available (i.e.,

information for the years 1976 through 1980 should be obtained and utilized to revise the forecast).

3. The linear trend forecast of Phase II should be continually updated as current data on actual cargo activity within MAC becomes available. The possibility does exist that as current information is obtained, a more definite trend may become evident. In addition, this cargo activity trend may suggest the employment of a different forecasting model.

4. More complete information pertaining to K-loader MMHs and operating hours should be obtained from the Vehicle Management Report. In this fashion, costs associated with maintenance and operation would probably be more accurate.

5. Cost information pertaining to fuel, oil, spare parts, indirect labor hours, salvage value, etc. should be acquired for both the dual and single loader systems. The acquisition of this information would result in a more complete cost analysis.

6. A cost analysis similar to that performed for the FMC loader should be also accomplished for any other "single system" cargo loaders being considered by MAC [i.e., loaders manufactured by Cochran Western and Cochran Boothe (37)]. These additional analyses would serve to verify whether the FMC loader was truly a representative "single system" loader.

7. Some sensitivity analysis should be performed to study the effects of changes in future cargo activity and loader replacement policy on the final solution to MAC's MHE problem.

8. A research effort should be directed such that MAC's MHE situation would be studied on a base level instead of an aggregate level. A base-level analysis would eliminate many of the simplifying assumptions which were made in this study. Therefore, a more realistic answer to MAC's problem could undoubtedly be obtained. This research team feels very confident that the implementation of these recommendations would definitely insure the attainment of an accurate solution to MAC's loader predicament.

APPENDIXES

APPENDIX A  
TRANSFORMATION OF NBA SUBSTITUTION EQUATION

General formula for substitution or logistic curve:

$$y = 1 - [1/(a + bc^t)]$$

where

$$0 \leq y \leq 1$$

$$a > 0$$

$$b > 0$$

$$c > 0$$

$$t \geq 0$$

Case 1.  $C > 1$

$$\text{LIM } y = 1 - (1/\infty) = 1 - 0 = 1$$

$$t \rightarrow \infty$$

This is invalid for the NBA scenario.

Case 2.  $0 < C < 1$

$$\text{LIM } y = 1 - (1/a)$$

$$t \rightarrow \infty$$

For this scenario, as  $t$  approaches infinity, the limit should equal zero.

$$\text{So, } 0 = 1 - (1/a)$$

$$a = 1$$

and

$$y = 1 - [1/(1 + bc^t)]$$

$$1 - y = 1/(1 + bc^t)$$

$$1/(1 - y) = 1 + bc^t$$

$$[1/(1 - y)] - 1 = bc^t$$

$$y/(1 - y) = bc^t$$

$$\text{LOG } y/(1 - y) = \text{LOG } bc^t$$

$$\text{LOG } y/(1 - y) = \text{LOG } b + (\text{LOG } c)(t)$$

Thus,

$$w = u + vt$$

where,

$$w = \text{LOG } y/(1 - y)$$

$$u = \text{LOG } b$$

$$v = \text{LOG } c$$

SOURCE: (3)

APPENDIX B  
REVENUE TONNAGE INFORMATION

**NBA REVENUE TONNAGE  
(IN BILLIONS)**

Year	Rev-Tons by Aircraft Type														Total Rev-Tons
	DC-8 -20	DC-3 -30	DC-8 -50	DC-8 -50F	DC-8 -61	DC-8 -62	DC-8 -63	DC-8 -63F	3-707 -100	B-707 -100B	B-707 -200	B-707 -300	B-707 -300B	B-707 -300C	
1970	0.931	0.291	0.976	0.350	1.895	0.435	0.226	1.193	0.225	1.974	0.051	0.622	2.981	3.278	15.429
1971	0.898	0.283	0.793	0.361	1.345	0.407	0.135	1.428	0.050	1.875	-----	0.323	2.813	3.125	13.826
1972	0.844	0.321	0.818	0.460	1.392	0.425	0.130	1.575	-----	1.958	-----	0.256	2.997	2.866	14.042
1973	0.631	0.329	0.844	0.464	1.321	0.433	0.021	1.481	-----	1.756	-----	0.195	2.916	2.607	12.998
1974	0.401	0.030	0.796	0.401	1.232	0.452	-----	1.404	-----	1.786	-----	0.178	2.742	2.362	11.784
1975	0.044	-----	0.678	0.297	1.183	0.407	-----	1.063	-----	1.736	-----	0.178	2.367	1.751	9.704

**SOURCE: (6:13-32; 7:13-32; 8:11-29; 9:11-28; 10:13-36).**

WBA REVENUE TONNAGE  
(IN BILLIONS)

Year	Rev-Tons by Aircraft Type					Total Rev-Tons
	DC-10-10	DC-10-40	B-747	B-747F	L-1011	
1970	-----	-----	1.819	-----	-----	1.819
1971	-----	-----	4.743	-----	-----	4.743
1972	1.015	-----	6.200	-----	0.179	7.394
1973	2.083	0.208	6.980	-----	0.668	9.939
1974	2.668	0.427	6.480	-----	1.694	11.269
1975	3.307	0.559	6.380	0.137	2.313	12.696

SOURCE: (6:13-32; 7:13-32; 8:11-29; 9:11-28; 10:13-36)

TOTAL REVENUE TONNAGE  
(IN BILLIONS)

Year	NBA Rev-Tons	WBA Rev-Tons	Total Rev-Tons
1970	15.429	1.819	17.248
1971	13.826	4.743	18.569
1972	14.042	7.394	21.436
1973	12.998	9.939	22.937
1974	11.784	11.296	23.053
1975	9.704	12.696	22.400

APPENDIX C  
CONSTRUCTION OF THE SUBSTITUTION  
RATE FORECAST

PARAMETER DEVELOPMENT FOR SUBSTITUTION RATE FORECAST

Year	Total Rev-Tons (billion tons)	WBA Rev-Tons (billion tons)	WBA Rev-Tons (%)	IAETR	z	z AVE
1970	17.248	1.819	10.55	1.42	0.710	
1971	18.569	4.743	25.54	0.35	0.175	
1972	21.436	7.394	34.49	0.26	0.130	0.232
1973	22.937	9.939	43.33	0.13	0.065	
1974	23.053	11.269	48.88	0.16	0.080	
1975	22.400	12.696	56.68			

# REVENUE TONNAGE TREND

Year (t)	WBA % (100f)	NBA % [100(1-f)]
1970	10.55	89.45
1971	25.54	74.46
1972	34.49	65.51
1973	43.33	56.67
1974	48.88	51.12
1975	56.68	43.32
1976	67.75	32.25
1977	76.97	23.03
1978	84.16	15.84
1979	89.42	10.58
1980	93.08	6.92
1981	95.53	4.47
1982	97.14	2.86
1983	98.18	1.82
1984	98.85	1.15
1985	99.27	0.73
1986	99.54	0.46
1987	99.71	0.29
1988	99.82	0.18
1989	99.89	0.11
1990	99.93	0.07
1991	99.95	0.05

APPENDIX D

COMPUTER FORMULATION OF THE PREDICTION INTERVAL  
FOR THE SUBSTITUTION RATE FORECAST

DATA USED IN DEVELOPING THE PREDICTION INTERVAL FOR THE  
SUBSTITUTION RATE FORECAST

Year	Coded Year (t)	Total Rev-Tons (billion tons)	NBA Rev-Tons (billion tons)	NBA Rev-Tons (%)	y	$\frac{y}{1-y}$	$\text{LOG } \frac{y}{1-y}$
1970	0	17.248	15.429	89.45	0.8945	8.48	0.93
1971	1	18.569	13.826	74.46	0.7446	2.92	0.47
1972	2	21.436	14.042	65.51	0.6551	1.90	0.28
1973	3	22.937	12.998	56.67	0.5667	1.31	0.12
1974	4	23.053	11.784	51.12	0.5112	1.05	0.02
1975	5	22.400	9.704	43.32	0.4332	0.76	-0.12

MLREG OUTPUT--PREDICTION INTERVAL FOR THE  
SUBSTITUTION RATE FORECAST

SINFIT/MULREG

\*\*\* REGRESSION ANALYSIS for MANAGERS \*\*\*

WANT INSTRUCTIONS? NO  
IF YOUR DATA IS ON A FILE, TYPE IN THE FILE DESCRIPTION.  
(...OTHERWISE CARRIAGE RETURN) ? LOG  
DOES YOUR FILE CONTAIN LINE NUMBERS? YES  
DO YOU WANT TO SEE THE VALUES AS THEY ARE BEING READ? YES

YOU SPECIFIED 6 OBSERVATIONS  
AND 3 VARIABLES. IS THAT CORRECT? YES  
ROW 1 : 1970.000 0. 0.930  
ROW 2 : 1971.000 1.000 0.470  
ROW 3 : 1972.000 2.000 0.280  
ROW 4 : 1973.000 3.000 0.120  
ROW 5 : 1974.000 4.000 0.020  
ROW 6 : 1975.000 5.000 -0.120

ARE THERE ANY ERRORS IN THE INPUT (Y OR N)? N  
WHAT COLUMN IS THE DEPENDENT VAR (Y) IN? 3  
HOW MANY INDEPENDENT VARIABLES (X)? 1  
COLUMN NUMBER(S) OF INDEPEDENT VARIABLE(S),  
SEPERATED BY COMMAS IF MORE THAN ONE? 2  
ENTER THE OPTION OF THE OUTPUT SET YOU WANT? 5

I. PREDICTION MODE

YOU HAVE 1 INDEPENDENT VARIABLES.  
YOU MUST ENTER A VALUE FOR EACH.  
ENTER THE VALUES IN THE FOLLOWING ORDER  
INDEPENDENT VARIABLE NUMBER 2  
IF MORE THAN ONE VALUE, SEPERATE YOUR INPUT  
WITH COMMAS.? 21  
\*POINT ESTIMATE = -3.28981  
STANDARD DEVIATION OF MEAN RESPONSE = 0.53897  
\*\*STANDARD DEVIATION OF INDIVIDUAL RESPONSE = 0.55246  
DO YOU WANT MORE PREDICTION? NO

\*w<sub>t<sub>c</sub></sub>

\*\*s(d<sub>t<sub>c</sub></sub>)

APPENDIX E  
SUMMARY OF MAC CARGO ACTIVITY

**MAC CARGO ACTIVITY--SUMMARY A**  
(IN TONS PER MONTH)

Year Flown By	Month											
	JA	FE	MA	AP	MA	JN	JL	AU	SE	OC	NO	DE
Military	35,109	35,160	41,887	43,182	50,973	55,539	54,458	53,305	48,321	47,562 <sup>a</sup>	45,137	41,184
1974 Civ.Non-ASIF	2,975	3,325	3,410	2,911	3,207	3,394	3,460	4,289	4,414	4,225 <sup>a</sup>	4,442	4,457
Civ.ASIF	3,125	3,051	4,050	2,658	2,747	2,876	2,355	2,184	2,245	2,396 <sup>a</sup>	2,427	2,142
Military	42,438	41,891	43,338	58,668	59,684	48,613	52,113	55,543	49,059	52,125	48,750	46,976
1975 Civ.Non-ASIF	4,679	4,210	4,711	4,808	5,136	4,575	4,653	4,481	4,757	4,061	4,442	4,666
Civ.ASIF	2,786	1,866	1,634	7,200	6,484	1,012	40	33	26	476	176	384
Military	39,865	33,555	36,916	36,054	41,212	41,530	44,267	44,008	43,011	40,334	41,970	40,169
1976 Civ.Non-ASIF	4,009	3,591	4,023	4,068	4,006	3,691	3,979	3,876	3,750	3,507	3,338	3,525
Civ.ASIF	3,745	3,397	3,329	1,893	4,019	3,468	116	1,185	637	2,262	1,406	1,231
Military	41,887	42,140	48,598	47,584	50,836	47,945	51,252	48,899	46,082	47,803	49,600	48,213
1977 Civ.Non-ASIF	3,202	3,241	3,449	3,630	3,804	3,600	3,608	3,627	3,341	3,511	3,247	3,632
Civ.ASIF	1,198	1,809	1,322	1,097	2,095	2,492	2,458	3,587	3,945	3,450	3,236	3,858
Military	39,725	40,925	49,375	50,057	46,584	47,127	45,579	47,210	42,739	49,431	44,877	48,675
1978 Civ.Non-ASIF	3,040	3,284	4,057	3,734	4,092	3,854	3,583	3,863	3,584	4,915	4,831	4,591
Civ.ASIF	4,655	4,335	5,070	4,740	4,432	4,974	5,657	6,538	5,781	5,424	4,514	4,569
Military	46,049	48,136	60,705	52,836	52,530	54,191	52,703	60,834	53,126	53,668	51,229	b
1979 Civ.Non-ASIF	4,519	4,401	5,727	5,676	5,252	5,202	5,277	5,262	5,028	5,311	4,904	b
Civ.ASIF	4,865	5,016	5,463	11,821	3,313	2,792	2,570	2,247	1,995	3,261	2,453	b

<sup>a</sup>Missing Travis AFB's tonnage; tonnage based on Travis AFB's 1974 average of 11 months.

<sup>b</sup>Unavailable tonnage data.

# MAC CARGO ACTIVITY--SUMMARY B

Year	Average Monthly Tonnage		
	Flown by Military and Civilian Non-ASIF	Flown by Civilian ASIF (WBA)	Total Flown
1974	49,694	2,688	52,382
1975	54,531	1,843	56,374
1976	44,021	2,224	46,245
1977	51,078	2,544	53,622
1978	49,978	5,057	55,035
1979	58,415 <sup>a</sup>	4,163 <sup>a</sup>	62,578 <sup>a</sup>

<sup>a</sup>Tonnage based on an eleven-month average.

APPENDIX F

COMPUTER DEVELOPMENT OF THE  
LINEAR TREND FORECAST

MLREG OUTPUT--REGRESSION LINE FOR  
TOTAL TONNAGE

SINFIT/MULREG

\*\*\* REGRESSION ANALYSIS for MANAGERS \*\*\*

WANT INSTRUCTIONS? NO  
IF YOUR DATA IS ON A FILE, TYPE IN THE FILE DESCRIPTION.  
(...OTHERWISE CARRIAGE RETURN) ? TOTAL  
DOES YOUR FILE CONTAIN LINE NUMBERS? YES  
DO YOU WANT TO SEE THE VALUES AS THEY ARE BEING READ? YES

YOU SPECIFIED 6 OBSERVATIONS  
AND 3 VARIABLES. IS THAT CORRECT? YES  
ROW 1 : 1974.000 4.000 5238.200  
ROW 2 : 1975.000 5.000 5637.400  
ROW 3 : 1976.000 6.000 4624.500  
ROW 4 : 1977.000 7.000 5362.200  
ROW 5 : 1978.000 8.000 5503.500  
ROW 6 : 1979.000 9.000 6257.800

ARE THERE ANY ERRORS IN THE INPUT (Y OR N)? N  
WHAT COLUMN IS THE DEPENDENT VAR (Y) IN? 3  
HOW MANY INDEPENDENT VARIABLES (X)? 1  
COLUMN NUMBER(S) OF INDEPEDENT VARIABLE(S),  
SEPERATED BY COMMAS IF MORE THAN ONE? 2  
ENTER THE OPTION OF THE OUTPUT SET YOU WANT? 3

C. VARIANCE-COVARIANCE MATRIX  
646364.67969-93019.27148  
-93019.27148 14310.65710

D. COEF OF DETERMINATION (R\*\*2) = 0.2963122

E. RESIDUAL STD DEV (SQRT(MSE)) = 500.4363098

F. ANALYSIS OF VARIANCE TABLE

SOURCE	VARIATIONS(SS)	DF	MEAN SQ	F
EXPLAINED(SSR)	421820.000000	1	421820.000000	1.684339
ERROR(SSE)	1001746.000000	4	250436.500000	
TOTAL(SST0)	1423566.000000	5		

G. COEFFICIENT TABLE

	COEFFICIENT	STD ERROR	T RATIO
a → B 0	4428.09497	803.96809	5.50780
b → B 2	155.25712	119.62716	1.29784

DO YOU WANT PREDICTION MODE? NO

MLREG OUTPUT--REGRESSION LINE  
FOR WBA TONNAGE

SINFIT/MULREG

\*\*\* REGRESSION ANALYSIS for MANAGERS \*\*\*

WANT INSTRUCTIONS? NO  
IF YOUR DATA IS ON A FILE, TYPE IN THE FILE DESCRIPTION.  
(...OTHERWISE CARRIAGE RETURN) ? CIV  
DOES YOUR FILE CONTAIN LINE NUMBERS? YES  
DO YOU WANT TO SEE THE VALUES AS THEY ARE BEING READ? YES

YOU SPECIFIED 6 OBSERVATIONS  
AND 3 VARIABLES. IS THAT CORRECT? YES  
ROW 1 : 1974.000 4.000 268.800  
ROW 2 : 1975.000 5.000 184.300  
ROW 3 : 1976.000 6.000 222.400  
ROW 4 : 1977.000 7.000 254.400  
ROW 5 : 1978.000 8.000 505.700  
ROW 6 : 1979.000 9.000 416.300

ARE THERE ANY ERRORS IN THE INPUT (Y OR N)? N  
WHAT COLUMN IS THE DEPENDENT VAR (Y) IN? 3  
HOW MANY INDEPENDENT VARIABLES (X)? 1  
COLUMN NUMBER(S) OF INDEPENDENT VARIABLE(S),  
SEPERATED BY COMMAS IF MORE THAN ONE? 2  
ENTER THE OPTION OF THE OUTPUT SET YOU WANT? 3

C. VARIANCE-COVARIANCE MATRIX  
22526.25488 -3241.78577  
-3241.78577 498.73627

D. COEF OF DETERMINATION (R\*\*2) = 0.5515554

E. RESIDUAL STD DEV (SQRT(MSE)) = 93.4231491

F. ANALYSIS OF VARIANCE TABLE

SOURCE	VARIATIONS(SS)	DF	MEAN SQ	F
EXPLAINED(SSR)	42938.750000	1	42938.750000	4.919720
ERROR(SSE)	34911.539063	4	8727.884766	
TOTAL(SSTO)	77850.289062	5		

G. COEFFICIENT TABLE

	COEFFICIENT	STD ERROR	T RATIO
c + b 0	-13.32285	150.08749	-0.08877
d + b 2	49.53428	22.33240	2.21805

DO YOU WANT PREDICTION MODE? NO

APPENDIX G

COMPUTER FORMULATION OF THE PREDICTION INTERVAL  
FOR THE LINEAR TREND FORECAST

MLREG OUTPUT--PREDICTION INTERVAL  
FOR TOTAL TONNAGE

SINFIT/MULREG

\*\*\* REGRESSION ANALYSIS for MANAGERS \*\*\*

WANT INSTRUCTIONS? NO  
IF YOUR DATA IS ON A FILE, TYPE IN THE FILE DESCRIPTION.  
(...OTHERWISE CARRIAGE RETURN) ? TOTAL  
DOES YOUR FILE CONTAIN LINE NUMBERS? YES  
DO YOU WANT TO SEE THE VALUES AS THEY ARE BEING READ? YES

YOU SPECIFIED 6 OBSERVATIONS  
AND 3 VARIABLES. IS THAT CORRECT? YES  
ROW 1 : 1974.000 4.000 5238.200  
ROW 2 : 1975.000 5.000 5637.400  
ROW 3 : 1976.000 6.000 4624.500  
ROW 4 : 1977.000 7.000 5362.200  
ROW 5 : 1978.000 8.000 5503.500  
ROW 6 : 1979.000 9.000 6257.800

ARE THERE ANY ERRORS IN THE INPUT (Y OR N)? N  
WHAT COLUMN IS THE DEPENDENT VAR (Y) IN? 3  
HOW MANY INDEPENDENT VARIABLES (X)? 1  
COLUMN NUMBER(S) OF INDEPEDENT VARIABLE(S),  
SEPERATED BY COMMAS IF MORE THAN ONE? 2  
ENTER THE OPTION OF THE OUTPUT SET YOU WANT? 5

1. PREDICTION MODE

YOU HAVE 1 INDEPENDENT VARIABLES.  
YOU MUST ENTER A VALUE FOR EACH.  
ENTER THE VALUES IN THE FOLLOWING ORDER  
INDEPENDENT VARIABLE NUMBER 2  
IF MORE THAN ONE VALUE, SEPERATE YOUR INPUT  
WITH COMMAS.? 21  
\*POINT ESTIMATE =7688.49445  
STANDARD DEVIATION OF MEAN RESPONSE =1746.58383  
\*\*STANDARD DEVIATION OF INDIVIDUAL RESPONSE =1816.86311  
DO YOU WANT MORE PREDICTION? NO

\* $T_{tc}$

\*\* $s(d_{tc})$

MLREG OUTPUT--PREDICTION INTERVAL  
FOR WBA TONNAGE

SINFIT/MULREG

\*\*\* REGRESSION ANALYSIS for MANAGERS \*\*\*

WANT INSTRUCTIONS? NO  
IF YOUR DATA IS ON A FILE, TYPE IN THE FILE DESCRIPTION.  
(...OTHERWISE CARRIAGE RETURN) ? CIV  
DOES YOUR FILE CONTAIN LINE NUMBERS? YES  
DO YOU WANT TO SEE THE VALUES AS THEY ARE BEING READ? YES

YOU SPECIFIED 6 OBSERVATIONS  
AND 3 VARIABLES. IS THAT CORRECT? YES  
ROW 1 : 1974.000 4.000 268.800  
ROW 2 : 1975.000 5.000 184.300  
ROW 3 : 1976.000 6.000 222.400  
ROW 4 : 1977.000 7.000 254.400  
ROW 5 : 1978.000 8.000 505.700  
ROW 6 : 1979.000 9.000 416.300

ARE THERE ANY ERRORS IN THE INPUT (Y OR N)? N  
WHAT COLUMN IS THE DEPENDENT VAR (Y) IN? 3  
HOW MANY INDEPENDENT VARIABLES (X)? 1  
COLUMN NUMBER(S) OF INDEPEDENT VARIABLE(S),  
SEPERATED BY COMMAS IF MORE THAN ONE? 2  
ENTER THE OPTION OF THE OUTPUT SET YOU WANT? 5

I. PREDICTION MODE

YOU HAVE 1 INDEPENDENT VARIABLES.  
YOU MUST ENTER A VALUE FOR EACH.  
ENTER THE VALUES IN THE FOLLOWING ORDER  
INDEPENDENT VARIABLE NUMBER 2  
IF MORE THAN ONE VALUE, SEPERATE YOUR INPUT  
WITH COMMAS.? 21  
\* POINT ESTIMATE =1026.89705  
STANDARD DEVIATION OF MEAN RESPONSE = 326.05820  
\*\* STANDARD DEVIATION OF INDIVIDUAL RESPONSE = 339.17817  
DO YOU WANT MORE PREDICTION? NO

\*T<sub>t<sub>c</sub></sub>

\*\*s(d<sub>t<sub>c</sub></sub>)

APPENDIX H  
FORECAST OF MAC CARGO ACTIVITY

Year	Coded Year ( $x_t$ )	AVERAGE MONTHLY TONNAGE		Total Flown
		Flown by Military Aircraft and Civilian Non-ASIF	Flown by Civilian ASIF (WBA)	
1981	11	56,043	5,316	61,359
1982	12	57,101	5,811	62,912
1983	13	58,158	6,306	64,464
1984	14	59,215	6,802	66,017
1985	15	60,273	7,297	67,570
1986	16	61,330	7,792	69,122
1987	17	62,387	8,288	70,675
1988	18	63,444	8,783	72,227
1989	19	64,502	9,278	73,780
1990	20	65,558	9,774	75,332
1991	21	66,616	10,269	76,885

APPENDIX I

ORIGINAL 40K LOADER ACQUISITIONS--  
EXISTING INVENTORY (BEGINNING-OF-YEAR PURCHASES)

Year	Number of Loaders
1968	2
1969	---
1970	8
1971	4
1972	15
1973	---
1974	5
1975	34
1976	24
1977	45
	137

APPENDIX J  
LOADER ACQUISITION PROFILES

LOADER ACQUISITION FOR DUAL LOADER SYSTEM  
(END-OF-YEAR PURCHASES)

Year	40K Loader										Cochran Elevator			
	8 Year Service Life			10 Year Service Life			12 Year Service Life			10 Year Economic Life				
	New Require- ment	Replace- ment	Total	New Require- ment	Replace- ment	Total	New Require- ment	Replace- ment	Total	New Require- ment	Replace- ment	Total	Inventory Level	Inventory Level
1981	2	34	36	2	29	31	2	10	12	1	--	1	12	12
1982	2	34	36	2	--	2	2	4	6	1	--	1	13	13
1983	2	24	26	2	5	7	2	15	17	1	--	1	14	14
1984	2	45	47	2	34	36	2	--	2	1	--	1	15	15
1985	2	--	2	2	24	26	2	5	7	1	--	1	16	16
1986	2	--	2	2	45	47	2	34	36	1	12	13	17	17
1987	2	--	2	2	--	2	2	24	26	1	--	1	18	18
1988	2	--	2	2	--	2	2	45	47	--	--	--	19	19
1989	2	36	38	2	--	2	2	--	2	--	--	--	19	19
1990	2	36	38	2	--	2	2	--	2	--	--	--	19	19
1991	--	26	26	--	31	31	--	--	--	--	1	1	10	10
Totals	20	235	255	20	168	188	20	137	157	7	13	20		

LOADER ACQUISITION FOR SINGLE LOADER SYSTEM  
(END-OF-YEAR PURCHASES)

Year	FMC Loader									
	10 Year Service Life					12 Year Service Life				
	New Requirement	Replacement	Total Acquisition	FMC Loader Inventory	40K Loader Inventory	New Requirement	Replacement	Total Acquisition	FMC Loader Inventory	40K Loader Inventory
1981	2	37	39	---	137	2	13	15	---	137
1982	3	---	3	39	108	3	5	8	15	127
1983	2	6	8	42	108	2	19	21	23	123
1984	3	42	45	50	103	3	---	3	44	108
1985	2	30	32	95	69	2	6	8	47	103
1986	3	57	60	127	45	3	42	45	55	103
1987	2	---	2	187	---	2	30	32	100	69
1988	3	---	3	189	---	3	57	60	132	45
1989	2	---	2	192	---	2	---	2	192	---
1990	3	---	3	194	---	3	---	3	194	---
1991	---	39	39	197	---	---	---	---	197	---
Totals	25	211	236			25	172	197		

APPENDIX K  
LOADER OPERATION AND MAINTENANCE INFORMATION

# VEHICLE MANAGEMENT REPORT SUMMARY

Year	40K Loader Management Code	Average Inventory	Average Direct Labor Hours per Vehicle	Average Operation Hours per Vehicle
1978	E938	16	2,900.0	2,613
1978	E939	16	272.5	644
1978	E940	12	344.3	794
1978	E941	44	290.0	641
1979	E938	3	1,029.0	766
1979	E939	12	336.3	466
1979	E940	13	367.9	768
1979	E941	40	239.2	528

SOURCE: (24)

WEIGHTED AVERAGE DETERMINATION OF AVERAGE  
ANNUAL HOURS OF OPERATION FOR 40K LOADER

Inventory		Average Operation Hours		
16	x	2,613	=	41,808
16	x	644	=	10,304
12	x	794	=	9,528
44	x	641	=	28,204
3	x	766	=	2,298
12	x	466	=	5,592
13	x	468	=	9,984
<u>40</u>	x	528	=	<u>21,120</u>
Σ 156				Σ 128,838

$$\frac{128,838}{156} = 826 \text{ Operation Hours per Vehicle}$$

WEIGHTED AVERAGE DETERMINATION OF AVERAGE  
ANNUAL MMH FOR 40K LOADER

Inventory		Average MMH	
16	x	2,900.0	= 46,400.0
16	x	272.5	= 4,360.0
12	x	344.3	= 4,131.6
44	x	290.0	= 12,760.0
3	x	1,029.0	= 3,087.0
12	x	336.3	= 4,035.6
13	x	367.9	= 4,782.7
<u>40</u>	x	239.2	= <u>9,568.0</u>
Σ 156			Σ 89,124.9

---


$$\frac{89,149.9}{156} = 571 \text{ Average MMH per Vehicle}$$


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APPENDIX L

AVERAGE HOURLY RATES FOR LOADER OPERATORS  
AND MAINTENANCE PERSONNEL (EFFECTIVE 1 OCTOBER 1979)

Level	Avg. Pay Rate (\$/Hr)	Weight	Overall Weighted Avg. Pay Rate (\$/Hr)
Enlisted Hourly Rates			
E-5	6.10	1	4.89
E-4	5.20	2	
E-3	4.40	2	
E-2	4.01	1	
Wage Grade Hourly Rates			
WG-6	8.03	1	7.55
WG-5	7.71	1	
WG-4	7.39	1	
WG-3	7.07	1	

NOTE: Hourly Wage Estimate = \$6.22 (Average  
of Enlisted Average Rate and Wage Grade Average Rate)

SOURCE: (45)

APPENDIX M

FMC LOADER AVERAGE ANNUAL MMH DETERMINATION  
(BASED ON 1979 DATA OF  
AMERICAN AIRLINE'S INVENTORY OF  
FMC LOADERS)

Labor Category	MMH*
Preventive Maintenance	665
Planned Repair	1,796
Breakdown	2,997
Paint	161
Major Modification**	548
Abuse or Accident	844

Average MMHs for FMC Loader =

$$\frac{(665 + 1,796 + 2,997 + 161 + 844)}{7}$$

$$= 923.29$$

\*Number of Units = 7

\*\*This type of labor would not be performed by Air Force personnel and was not included in the determination of average MMH.

SOURCE: (2)

APPENDIX N  
DUAL LOADER SYSTEM ACQUISITION OUTLAYS

ACQUISITION OUTLAYS FOR DUAL LOADER SYSTEM  
(BASED ON 8 YEAR SERVICE LIFE FOR 40K LOADER)

Year	Number of 40K Purchased	40K Acquisition Cost (\$) (1)	Number of Elevators Purchased	Elevator Acquisition Cost (\$) (2)	Total Acquisition Cost (\$) (1) + (2)
1981	36	6,024,960	1	119,870	6,144,830
1982	36	6,024,960	1	119,870	6,144,830
1983	26	4,351,360	1	119,870	4,471,230
1984	47	7,865,920	1	119,870	7,985,790
1985	2	334,720	1	119,870	454,590
1986	2	334,720	13	1,558,310	1,893,030
1987	2	334,720	1	119,870	454,590
1988	2	334,720	0	-----	334,720
1989	38	6,359,680	0	-----	6,359,680
1990	38	6,359,680	0	-----	6,359,680
1991	26	4,351,360	1	119,870	4,471,230

ACQUISITION OUTLAYS FOR DUAL LOADER SYSTEM  
(BASED ON 10 YEAR SERVICE LIFE FOR 40K LOADER)

Year	Number of 40K Purchased	40K Acquisition Cost (\$) (1)	Number of Elevators Purchased	Elevator Acquisition Cost (\$) (2)	Total Acquisition Cost (\$) (1) + (2)
1981	31	5,118,160	1	119,870	5,308,030
1982	2	334,720	1	119,870	454,590
1983	7	1,171,520	1	119,870	1,291,390
1984	36	6,024,960	1	119,870	6,144,830
1985	26	4,351,360	1	119,870	4,471,230
1986	47	7,865,920	13	1,558,310	9,424,230
1987	2	334,720	1	119,870	454,590
1988	2	334,720	0	-----	334,720
1989	2	334,720	0	-----	334,720
1990	2	334,720	0	-----	334,720
1991	31	5,188,160	1	119,870	5,308,030

ACQUISITION OUTLAYS FOR DUAL LOADER SYSTEM  
(BASED ON 12 YEAR SERVICE LIFE FOR 40K LOADER)

Year	Number of 40K Purchased	40K Acquisition Cost (\$) (1)	Number of Elevators Purchased	Elevator Acquisition Cost (\$) (2)	Total Acquisition Cost (\$) (1) + (2)
1981	12	2,008,320	1	119,870	2,128,190
1982	6	1,004,160	1	119,870	1,124,030]
1983	17	2,845,120	1	119,870	2,964,990
1984	2	334,720	1	119,870	454,590
1985	7	1,171,520	1	119,870	1,291,390
1986	36	6,024,960	13	1,558,310	7,583,270
1987	26	4,351,360	1	119,870	4,471,230
1988	47	7,865,920	0	-----	7,865,920
1989	2	334,720	0	-----	334,720
1990	2	334,720	0	-----	334,720
1991	0	-----	1	119,870	119,870

APPENDIX O  
SINGLE LOADER SYSTEM ACQUISITION OUTLAYS

ACQUISITION OUTLAYS FOR SINGLE LOADER SYSTEM  
(BASED ON 10 YEAR SERVICE LIFE FOR 40K  
AND FMC LOADER)

Year	Number of FMC Purchased	Acquisition Cost (\$)
1981	39	11,317,917
1982	3	870,609
1983	8	2,321,624
1984	45	13,059,135
1985	32	9,286,496
1986	60	17,412,180
1987	2	580,406
1988	3	870,609
1989	2	580,406
1990	3	870,609
1991	39	11,317,917

ACQUISITION OUTLAYS FOR SINGLE LOADER SYSTEM  
(BASED ON 12 YEAR SERVICE LIFE FOR 40K  
AND FMC LOADER)

Year	Number of FMC Purchased	Acquisition Cost (\$)
1981	15	4,353,045
1982	8	2,321,624
1983	21	6,094,263
1984	3	870,609
1985	8	2,321,624
1986	45	13,059,135
1987	32	9,286,496
1988	60	17,412,180
1989	2	580,406
1990	3	870,609
1991	0	-----

APPENDIX P  
LOADER OPERATION COSTS (DUAL SYSTEM)

Year	No. of Vehicles (40K)	<u>Tons WBA</u> Tons Total	Operating Cost (\$)
1981	137	.087	61,236
1982	139	.092	65,701
1983	141	.098	70,993
1984	143	.103	75,673
1985	145	.108	80,457
1986	147	.113	85,343
1987	149	.117	89,566
1988	151	.122	94,647
1989	153	.126	99,045
1990	155	.130	103,525
1991	157	.134	108,087

APPENDIX Q  
MAINTENANCE MAN-HOUR COSTS FOR  
DUAL LOADER SYSTEM

MAINTENANCE MAN-HOUR COSTS FOR DUAL LOADER SYSTEM  
(40K LOADER)

Year	Number of 40K Loaders	MMH Cost (\$)
1981	137	486,572
1982	139	493,675
1983	141	500,778
1984	143	507,882
1985	145	514,935
1986	147	522,088
1987	149	529,191
1988	151	536,295
1989	153	543,398
1990	155	550,501
1991	157	557,604

MAINTENANCE MAN-HOUR COSTS FOR DUAL LOADER SYSTEM  
(COCHRAN ELEVATOR)

Year	Number of Elevators	MMH Cost (\$)
1981	12	3,135
1982	13	3,396
1983	14	3,657
1984	15	3,919
1985	16	4,180
1986	17	4,441
1987	18	4,702
1988	19	4,964
1989	19	4,964
1990	19	4,964
1991	19	4,964

APPENDIX R  
MAINTENANCE MAN-HOUR COSTS FOR  
SINGLE LOADER SYSTEM

MAINTENANCE MAN-HOUR COSTS FOR CONVERSION TO SINGLE LOADER SYSTEM  
(BASED ON 10 YEAR SERVICE LIFE FOR 40K LOADER AND FMC LOADER)

Year	Number of 40K Loaders	MMH Cost of Loaders (\$)	Number of Elevators	MMH Cost of Elevators (\$)	Number of FMC Loaders	MMH Cost of FMC Loaders (\$)
1981	137	486,572	12	3,132	---	-----
1982	108	383,574	---	-----	39	223,977
1983	108	383,575	---	-----	42	241,199
1984	103	365,817	---	-----	50	287,142
1985	69	245,062	---	-----	95	545,570
1986	45	159,823	---	-----	127	729,341
1987	---	-----	---	-----	187	1,073,914
1988	---	-----	---	-----	189	1,085,395
1989	---	-----	---	-----	192	1,102,625
1990	---	-----	---	-----	194	1,114,111
1991	---	-----	---	-----	197	1,131,339

MAINTENANCE MAN-HOUR COSTS FOR CONVERSION TO SINGLE LOADER SYSTEM  
(BASED ON 12 YEAR SERVICE LIFE FOR 40K LOADER AND FMC LOADER)

Year	Number of 40K Loaders	MMH Cost of Loaders (\$)	Number of Elevators	MMH Cost of Elevators (\$)	Number of FMC Loaders	MMH Cost of FMC Loaders (\$)
1981	137	486,572	12	3,132	---	-----
1982	127	451,056	---	-----	15	86,143
1983	123	436,849	---	-----	23	132,085
1984	108	383,575	---	-----	44	252,685
1985	108	383,575	---	-----	47	269,913
1986	108	383,575	---	-----	55	315,856
1987	69	245,062	---	-----	100	374,284
1988	45	159,823	---	-----	132	758,056
1989	---	-----	---	-----	192	1,102,625
1990	---	-----	---	-----	194	1,114,111
1991	---	-----	---	-----	197	1,131,339

APPENDIX S  
INFLATION PLANNING DATA

# INFLATION PLANNING DATA--MILITARY COMPENSATION

Year	Total Military Compensation Raw Inflation Index ( $I_t$ )	Year-to-Year Inflation Index $[I_t / (I_{t-1})]$	Inflation Rate (%)	Average Inflation Rate (%)
1980	1.000	1.077	7.7	
1981	1.077	1.081	8.1	
1982	1.164	1.078	7.8	
1983	1.255	1.073	7.3	7.6
1984	1.347	1.073	7.3	
1985	1.445	1.073	7.3	
1986	1.551	1.073	7.3	

SOURCE: (42:112)

INFLATION PLANNING DATA--CIVILIAN PAY

Year	Civilian Personnel Pay Raw Inflation Index ( $I_t$ )	Year-to-Year Inflation Index $[I_t / (I_{t-1})]$	Inflation Rate (%)	Average Inflation Rate (%)
1980	1.000			
1981	1.064	1.064	6.4	
1982	1.143	1.074	7.4	
1983	1.229	1.075	7.5	7.1
1984	1.318	1.072	7.2	
1985	1.412	1.071	7.1	
1986	1.514	1.072	7.2	

SOURCE: (42:112)

# INFLATION PLANNING DATA--PROCUREMENT

Year	Procurement Raw Inflation Index ( $I_t$ )	Year-to-Year Inflation Index ( $I_t/(I_{t-1})$ )	Inflation Rate (%)	Average Inflation Rate (%)
1980	1.000			
1981	1.090	1.090	9.0	
1982	1.183	1.085	8.5	
1983	1.275	1.078	7.8	
1984	1.364	1.070	7.0	7.4
1985	1.447	1.061	6.1	
1986	1.536	1.062	6.2	

SOURCE: (42:112)

AD-A087 094

AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 15/5  
AN ANALYSIS OF THE FUTURE REQUIREMENTS FOR MATERIALS HANDLING E--ETC(U)  
JUN 80 C CARSON, C D MUNSON  
AFIT-LSSR-35-80

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APPENDIX T  
PRESENT VALUE ANALYSIS

# 10 PERCENT PRESENT VALUE FACTORS

Number*	Discount Factor
1	.9091
2	.8264
3	.7513
4	.6830
5	.6209
6	.5645
7	.5132
8	.4665
9	.4241
10	.3855
11	.3505

\*Number = Number of Periods from Base Period.

SOURCE: (28:174; 38:368)

PRESENT VALUE ANALYSIS OF DUAL LOADER SYSTEM  
(BASED ON 8 YEAR SERVICE LIFE FOR 40K LOADER)

Year	Acquisition Cost (\$)	Operating Cost (\$)	40K MMH Cost (\$)	Elevator MMH Cost (\$)	Undiscounted Total Cost (\$)	Discount Factor	Discounted Total Cost (\$)
1981	6,144,830	61,236	486,572	3,135	6,695,773	.9091	6,087,127
1982	6,144,830	65,701	493,675	3,396	6,707,602	.8264	5,543,162
1983	4,471,230	70,993	500,778	3,657	5,046,658	.7513	3,791,554
1984	7,985,790	75,673	507,882	3,919	8,573,264	.6830	5,855,539
1985	454,590	80,457	514,985	4,180	1,054,212	.6209	654,560
1986	1,893,030	85,343	522,088	4,441	2,504,902	.5645	1,414,017
1987	454,590	89,566	529,191	4,702	1,078,049	.5132	553,255
1988	334,720	94,647	536,295	4,964	970,626	.4665	452,797
1989	6,359,680	99,045	543,398	4,964	7,007,087	.4241	2,971,706
1990	6,359,680	103,525	550,501	4,964	7,018,670	.3855	2,705,697
1991	4,471,230	108,087	557,604	4,964	5,141,885	.3505	1,802,231
							<u>\$31,831,645</u>

PRESENT VALUE ANALYSIS OF DUAL LOADER SYSTEM  
(BASED ON 10 YEAR SERVICE LIFE FOR 40K LOADER)

Year	Acquisition Cost (\$)	Operating Cost (\$)	40K MMH Cost (\$)	Elevator MMH Cost (\$)	Undiscounted Total Cost (\$)	Discount Factor	Discounted Total Cost (\$)
1981	5,308,030	61,236	486,572	3,135	5,858,973	.9091	5,326,392
1982	454,590	65,701	493,675	3,396	1,017,362	.8264	840,748
1983	1,291,390	70,993	500,778	3,657	1,866,818	.7513	1,402,540
1984	6,144,830	75,673	507,882	3,919	6,732,304	.6830	4,598,164
1985	4,471,230	80,457	514,985	4,180	5,070,852	.6209	3,148,492
1986	9,424,230	85,343	522,088	4,441	10,036,102	.5645	5,665,380
1987	454,590	89,566	529,191	4,702	1,078,049	.5132	553,255
1988	334,720	94,647	536,259	4,964	970,626	.4665	452,797
1989	334,720	99,045	543,398	4,964	982,127	.4241	416,520
1990	334,720	103,525	550,501	4,964	993,710	.3855	383,075
1991	5,308,030	108,087	557,604	4,964	5,978,685	.3405	<u>2,095,529</u>
							\$24,882,892

PRESENT VALUE ANALYSIS OF DUAL LOADER SYSTEM  
(BASED ON 12 YEAR SERVICE LIFE FOR 40K LOADER)

Year	Acquisition Cost (\$)	Operation Cost (\$)	40K MMH Cost (\$)	Elevator MMH Cost (\$)	Undiscounted Total Cost (\$)	Discount Factor	Discounted Total Cost (\$)
1981	2,128,190	61,236	486,572	3,135	2,679,133	.9091	2,435,600
1982	1,124,030	65,701	493,675	3,396	1,686,802	.8264	1,393,973
1983	2,964,990	70,993	500,778	3,657	3,540,418	.7513	2,659,916
1984	454,590	75,673	507,882	3,919	1,042,064	.6830	711,730
1985	1,291,390	80,457	514,985	4,180	1,891,012	.6209	1,174,129
1986	7,583,270	85,343	522,088	4,441	8,195,142	.5645	4,626,158
1987	4,471,230	89,566	529,191	4,702	5,094,689	.5132	2,614,594
1988	7,865,920	94,647	536,295	4,964	8,501,826	.4665	3,966,102
1989	334,720	99,045	543,398	4,964	982,127	.4241	416,520
1990	334,720	103,525	550,501	4,964	993,710	.3855	383,075
1991	119,870	108,087	557,604	4,964	790,525	.3505	277,079
							<u>\$20,658,876</u>

PRESENT VALUE ANALYSIS OF SINGLE LOADER SYSTEM  
(BASED ON 10 YEAR SERVICE LIFE FOR 40K LOADER AND FMC LOADER)

Year	Acquisition Cost (\$)	MMH COST (\$)			Total Undiscounted Cost (\$) (1)	Discount Factor (2)	Total Discounted Cost (\$) (1)x(2)
		40K	Elevator	FMC			
1981	11,317,917	486,572	3,137	-----	11,807,621	.9091	10,734,308
1982	870,609	383,575	-----	223,977	1,478,161	.8264	1,221,552
1983	2,321,624	383,575	-----	241,199	2,946,398	.7513	2,213,629
1984	13,059,135	365,817	-----	287,142	13,712,094	.6830	9,365,360
1985	9,286,496	245,062	-----	545,570	10,077,128	.6209	6,256,889
1986	17,412,180	159,823	-----	729,341	18,301,344	.5645	10,331,109
1987	580,406	-----	-----	1,073,911	1,654,317	.5132	848,995
1988	870,609	-----	-----	1,085,397	1,956,006	.4665	912,477
1989	580,406	-----	-----	1,102,625	1,683,031	.4241	713,773
1990	870,609	-----	-----	1,114,111	1,984,720	.3855	765,110
1991	11,317,917	-----	-----	1,131,339	12,449,256	.3505	4,363,464

47,726,666

PRESENT VALUE ANALYSIS OF SINGLE LOADER SYSTEM  
(BASED ON 12 YEAR SERVICE LIFE FOR 40K LOADER AND FMC LOADER)

Year	Acquisition Cost (\$)	MMH COST (\$)			Total Undiscounted Cost (\$) (1)	Discount Factor (2)	Total Discounted Cost (\$) (1)x(2)
		40K	Elevator	FMC			
1981	4,353,045	486,572	3,132	-----	4,842,749	.9091	4,402,543
1982	2,321,624	451,056	-----	86,143	2,858,823	.8264	2,362,531
1983	6,094,263	436,849	-----	132,085	6,663,197	.7513	5,006,060
1984	870,609	383,575	-----	252,685	1,506,869	.6830	1,029,192
1985	2,321,624	383,575	-----	269,913	2,975,112	.6209	1,847,247
1986	13,059,135	365,817	-----	315,856	13,740,808	.5645	7,756,686
1987	9,286,496	245,062	-----	574,284	10,105,842	.5132	5,186,318
1988	17,412,180	159,823	-----	758,056	18,330,059	.4665	8,550,972
1989	580,406	-----	-----	1,102,625	1,683,031	.4241	713,773
1990	870,609	-----	-----	1,114,111	1,984,720	.3855	765,110
1991	-----	-----	-----	1,131,339	1,131,339	.3505	396,534
							38,016,966

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